

System Assessment and Validation for Emergency Responders (SAVER)

CCTV Technology Handbook

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FOREWORD

The U.S. Department of Homeland Security (DHS) established the System Assessment and Validation for Emergency Responders (SAVER) Program to assist emergency responders making procurement decisions. Located within the Science and Technology Directorate (S&T) of DHS, the SAVER Program conducts objective assessments and validations on commercial equipment and systems and provides those results along with other relevant equipment information to the emergency response community in an operationally useful form. SAVER provides information on equipment that falls within the categories listed in the DHS Authorized Equipment List (AEL). The SAVER Program mission includes:

- Conducting impartial, practitioner-relevant, operationally oriented assessments and validations of emergency responder equipment; and
- Providing information, in the form of knowledge products, that enables decision-makers and responders to better select, procure, use, and maintain emergency responder equipment.

Information provided by the SAVER Program will be shared nationally with the responder community, providing a life- and cost-saving asset to DHS, as well as to Federal, state, and local responders.

The SAVER Program is supported by a network of Technical Agents who perform assessment and validation activities. Further, SAVER focuses primarily on two main questions for the emergency responder community: "What equipment is available?" and "How does it perform?"

As a SAVER Program Technical Agent, the Space and Naval Warfare Systems Center (SPAWARSYSCEN) Atlantic has been tasked to provide expertise and analysis on key subject areas, including communications, sensors, security, weapon detection, and surveillance, among others. In support of this tasking, SPAWARSYSCEN Atlantic prepared the *CCTV Technology Handbook*. CCTV Technologies fall under AEL reference number 14SW-01-VIDA: Systems, Video Assessment, Security.

Visit the SAVER section of the DHS S&T website for more information on the SAVER Program or to view additional reports on CCTV or other technologies.

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PREFACE

PURPOSE

This *CCTV Technology Handbook* provides emergency responders, law enforcement security managers, and other security specialists with a reference to aid in planning, designing, and purchasing a CCTV system. This handbook includes a description of the capabilities and limitations of CCTV components used in security applications.

SCOPE

The CCTV technologies described in this handbook include cameras, lenses, monitors, multiplexers, recorders, transmission systems, and Internet protocol (IP)-based systems. This handbook also provides considerations for implementing a CCTV system. An overview of video analytics and programmatic considerations such as design, data storage and retention, cyber security strategies, and system integration is also included. The outlook for new or improved CCTV capabilities is briefly discussed. Information provided in this handbook was gathered from Internet research and consultations with subject matter experts. No assertion is made that this handbook is comprehensive in its breadth or depth. It is introductory-level information and should not be considered a definitive reference for planning or implementing a CCTV system. Such efforts should be undertaken only in consultation with organizations experienced in the various phases of planning, constructing, testing, operating, and maintaining comprehensive CCTV systems for access control, surveillance, or forensic applications.

The U.S. Government did not conduct independent tests of any CCTV products or systems and does not warrant, guarantee, or endorse any specific products. CCTV technologies under development or restricted to military use are not included in this handbook.

1. INTRODUCTION

CCTV systems provide surveillance capabilities used in the protection of people, assets, and systems. A CCTV system serves mainly as a security force multiplier, providing surveillance for a larger area, more of the time, than would be feasible with security personnel alone. CCTV systems are often used to support comprehensive security systems by incorporating video coverage and security alarms for barriers, intrusion detection, and access control. For example, a CCTV system can provide the means to assess an alarm generated by an intrusion detection system and record the event.

A CCTV system links a camera to a video monitor using a direct transmission system. This differs from broadcast television where the signal is transmitted over the air and viewed with a television. New approaches within the CCTV industry are moving towards more open architecture and transmission methods versus the closed circuit, hard-wired connection systems of the past.

CCTV systems have many components with a variety of functions, features, and specifications. Key components include cameras, lenses, data distribution, power, and lighting, among others. CCTV technologies continuously undergo feature refinements to improve performance in areas such as digital equipment options, data storage, component miniaturization, wireless communications, and automated image analysis.

The components, configuration options, and features available in today's CCTV market create a complex set of purchasing options. It is the intent of this handbook to provide information on the capabilities and limitations of CCTV components that will aid an agency procuring a new CCTV system or upgrading an existing one.

2. CCTV SYSTEM DESIGN

Following a sound design process enables organizations to make purchasing decisions that result in the procurement and installation of a CCTV system that meets functional and operational requirements. As CCTV is part of a multi-layered security approach, a system design should begin with a comprehensive needs assessment to ensure security risks and mitigation plans are identified. Clear requirements, a comprehensive site survey, and proper equipment selection and installation must all be considered when designing a CCTV system.

2.1 Defining System Requirements

In order for an organization to properly implement a CCTV system, site-specific characteristics need to be assessed by a knowledgeable multidisciplinary team of personnel. This team is critical to identifying key functional and operational requirements. Functional requirements consist of determining the area of surveillance, such as a perimeter area or an access point. Operational requirements define what information a CCTV system will be expected to provide given the existing operating conditions.

2.1.1 Multidisciplinary System Design Team

Organizations should begin by establishing a team of people with relevant knowledge to help guide the CCTV system design process. The system design team should be involved in all

phases of the project to include: needs assessment, requirements development, system design and layout, procurement, installation, and final check-out of the system. Personnel should be included from varied internal disciplines such as security, facility maintenance and management, and those who work directly with assets on-site or in controlled monitoring environments. The team may opt to consult with external subject matter experts, such as electricians, systems engineers, and information technology (IT) professionals.

2.1.2 Needs Assessment

A thorough risk and needs assessment should be conducted to identify locations or assets that will benefit from CCTV surveillance as part of an overall security approach. Organizations can enhance the security of facilities and critical infrastructure most effectively by defining their overall goals and objectives for CCTV systems in terms of the requirements within their operational environment.

A needs assessment gathers and analyzes four sets of requirements: functional, operational, infrastructure, and video retention.

- **Functional requirements**–Define camera coverage needs such as surveillance of perimeters, parking lots, and storage areas; surveillance of approaches to, and spaces within, buildings or other structures; and surveillance of waterfronts;
- **Operational requirements–**Define the capabilities of the CCTV system components that will enable it to provide the expected information under all operating conditions. Conditions to consider in the operational environments include day and night operations, lighting, weather conditions, and temperature changes. It is important that operational requirements are detailed and testable. For example, waterfront surveillance may demand that the CCTV system provide a recognizable image, during day or night, of any type of surface watercraft operating at speeds between 0 and 60 knots in wave heights of up to 6 feet while within 500 yards of a pier;
- **Infrastructure requirements–**Define needs for installing or accessing fiber or hard-wire cables, wireless networks, and power sources, to name a few, necessary to successfully implement an integrated CCTV system; and
- **Video retention requirements**–Define the organization's video retention and storage needs.

2.1.3 CCTV Site Survey

A CCTV system's effectiveness can be enhanced when integrated with access control, intrusion detection, or duress systems. Successful integration requires a comprehensive site survey which supports the development of detailed equipment specifications, installation design, and ultimately a thorough system test.

A site survey should address all aspects of specifying and building a CCTV system and it is an integral part of defining the requirements for discrete tasks and the role of each piece of equipment. Whenever possible, CCTV systems should be included in the planning and design stage of any new asset to ensure all necessary infrastructure requirements are adequately incorporated into the overall facility or asset design.

The result of a comprehensive survey of the area in which a CCTV system is to be installed or upgraded provides input to the requirements and design process. Considerations inherent in a site survey include the number of operators, local and remote operator consoles, layout, light levels, camera and lens selection and location, and power and data transmission.

2.1.4 System Layout Considerations

A key input to the design and specification of the layout of an outdoor CCTV system is the site survey team's collection and analysis of aerial photographs. Images can be obtained from a wide variety of sources such as satellite photographs, local government files, privately contracted aerial photography services, and a host of free web-based mapping applications. Aerial photographs can provide information regarding on-site distances and blind areas where outdoor video coverage may be needed. Additionally, aerial photographs and detailed maps can be used during the design of the system to overlay alarm and video information useful for planning the dispatch routes of response personnel.

Interior surveys are similar to exterior surveys. Aerial photographs can be replaced with scaled computer aided drawings or blueprints of the facility being surveyed. These can be used to mark potential camera site locations to identify the necessary coverage of access points, critical assets, and desired fields of view. A camcorder is often used to determine camera positions and evaluate video images from proposed camera locations.

An important factor in the design and layout of a CCTV system is the location of its transmission hubs. Transmission routes channeled through a primary transmission hub could lead to a single point of failure in which an outage of one transmitter could disable the transmission of data from other camera sites.

2.2 CCTV System Design Considerations

System design considerations include factors such as lighting, power, transmission, and cost. These factors are important in the design and layout of a CCTV system. In addition to these factors, camera types, lenses, monitors, multiplexers, and other components are also important considerations, and are discussed in Section 3.

Selection of the CCTV components is an iterative process that takes place in conjunction with the design phase. Section 3 contains more details on common component features and specifications that should be considered when selecting equipment for a CCTV system.

2.2.1 Lighting

Lighting strategies, camera selection, and camera location should be considered together in the design of a CCTV system to ensure optimum performance and to prevent operational environment conflicts. Light (or illumination) levels, both natural and artificial, affect system requirements at different times of the day for exterior systems. Exterior cameras often require lenses with automatic apertures to compensate for changes in light levels. Interior cameras may require internal software to compensate for backlight, which is the contrast between low interior light levels and high exterior daytime light levels. For example, backlight compensation allows security personnel to see details of a person moving in front of a brightly lit window. Artificial lighting can affect the appearance of the image as well as the operation of the CCTV system.

Types of artificial lights include:

- **Fluorescent**–Primarily used for indoor areas in the United States, these lights produce a 60-hertz (Hz) flicker that can interfere with image quality;
- **Incandescent**–Include halogen bulbs and are used to illuminate large outdoor areas. Incandescent lights consume more power than other lighting types and are generally the most expensive to operate;
- **High-intensity discharge (HID)**–Include high- and low-pressure sodium and metal-halide lighting and are the least expensive to operate. Low-pressure sodium lights produce a yellow light that may distort true color reproduction on video. Metal-halide lights provide the best color resolution. These types of lights require a few minutes to reach their full luminance once turned on;
- **Infrared (IR)**–Emit light at a much longer wavelength than white lights, and are faintly visible to the human eye as a red glow or they are not visible at all. IR lighting provides a longer illumination range than white light and can be used for discrete or covert CCTV system illumination. IR light can be provided by light emitting diodes (LEDs) and lasers as well as filters on incandescent bulbs; and
- **LED**–Provide high levels of brightness and intensity. These lights are highly efficient, and generate low levels of radiated heat. As such, they are increasingly used in CCTV systems.

It is important to verify that the selected lighting technology sufficiently illuminates the area of interest to meet the operational requirements. An overview of CCTV illumination is provided in the *Illumination for Closed Circuit Television Surveillance Systems TechNote*. Detailed information concerning lighting as it applies to security systems is available in the *Security Lighting Guide*. Both of these documents can be found in the the SAVER section of the DHS S&T website.

2.2.2 Power Distribution

A number of considerations must be taken into account when designing the power distribution system. Therefore, it is prudent to consult licensed engineers and electricians in the design and installation of a CCTV power distribution system.

Inadequate power is one of the most common problems with CCTV equipment and can often be the cause of erratic or sporadic equipment behavior. Proper system performance requires a clean, adequate power source. For example, it is possible for power to fluctuate considerably on hot days when air conditioning units overload power grids. Therefore, agencies should plan accordingly and specify power conditioning or backups as needed. The stability of the input power to CCTV equipment can be determined by taking several readings of the voltage and current levels over a short time period, or by using a voltage recorder for long-term monitoring.

An inadequate power system can affect the quality of the video across the entire system. Placement of power components is an important design consideration. Placing low-voltage power components near high-voltage lines can induce currents in the low-voltage system, presenting a hazard to personnel and equipment. Alternatively, placing a power source too far away can cause power fluctuations and also drive the installation costs up due to the larger conductor sizes needed to reduce voltage drop over long distances. Therefore, it is advisable to

locate power sources close to CCTV equipment. In addition, uninterruptible power supplies (UPSs) are beneficial in protecting equipment and conditioning the power. Since there are many types of UPS products on the market, it is important to find models appropriate to the application. Determinations about backup power requirements during a power interruption are also important. For example, some CCTV systems may have designated primary cameras focused on critical access points with a need for longer term backup power than secondary cameras such as those within internal corridors.

Voltage spikes and lightning are common phenomena affecting CCTV systems. Lightning, a common cause of voltage spikes, may cause failures and disable major pieces of equipment in buildings. When designing a system, all pieces of electronic equipment should have sufficient lightning suppression to help reduce damage and failures. Ground loop correctors help prevent voltage differentials between two or more installations or pieces of equipment powered by separate power sources (i.e., the ground loop corrector puts the separate pieces of equipment at the same ground potential).

Components of a CCTV system should ideally have an internal regulated power supply; however, this feature is often eliminated to reduce cost. This is particularly likely with low cost cameras. There are power supplies available that distribute individually fused and regulated feeds for each camera from a central location.

2.2.3 Video Transmission

Selecting the appropriate video transmission media, such as coaxial cable or unshielded twisted pair (UTP), is one of the most important aspects of designing a quality CCTV system. A system may include the highest quality hardware components available, but if the video signal is not transmitted by the proper media, overall performance could be degraded. Many common problems with video image quality can be avoided by selecting the appropriate transmission media and following proper installation techniques and procedures.

As CCTV technology has evolved, video transmission has progressed from analog to digital transmission. New cameras with Internet protocol (IP) capability transmit compressed video as digital data. A drawback of IP transmissions is that video places a high demand on a network's bandwidth, and the tradeoff may be image quality. One potential solution for this issue is to separate the video stream from the primary network. Section 4 provides a more detailed discussion on video transmission and IP-based CCTV systems.

2.2.4 Scalability

Scalability of CCTV systems refers to the ability of the system to accommodate additional components such as cameras, increased video storage, and additional monitors. Large facilities often implement CCTV systems in stages due to budget limitations or in order to verify system performance. The ability to easily incorporate hardware and software updates should be a consideration of a CCTV system design.

2.2.5 Cost

Cost estimates for a CCTV system should cover all aspects of the system's life cycle including planning, design, installation, operation, maintenance, and personnel costs. In addition,

long-term personnel costs, such as initial and refresher training programs should be included. Hardware and software upgrades should also be a cost consideration.

Using existing CCTV infrastructure such as cameras, camera mounts, and cable runs may reduce costs. However, as the capabilities of cameras and information handling components of CCTV advance, replacing old equipment and infrastructure may improve system performance and be a more cost-effective solution.

2.2.6 Infrastructure

Each camera deployed in a CCTV system requires power and the means to transmit video data to monitoring and storage systems. These requirements can necessitate modifications to a facility's infrastructure, such as installing new poles for mounting cameras. When planning a CCTV installation, there are four important considerations:

1) To what extent can the system use existing infrastructure?
2) To what extent can the new CCTV system integrate with existing enterprise systems?
3) To what extent can the new CCTV system integrate with or complement other existing or planned intrusion detection and access control systems?
4) To what extent can the new system operate in parallel with existing systems and which system will influence operational procedures and response?

Employing existing infrastructure is an important factor in controlling equipment and installation costs. For example, old coaxial cable systems can be converted to IP systems by running Ethernet over coaxial cable with a converter module. Analog video and Ethernet can also be run over telephone lines.

The extent to which a CCTV system integrates with the overall security program will be a major factor in its effectiveness. Any new installation should operate in parallel with existing systems until the new system is accepted and the old system upgraded or phased out. See Section 7 for more details on system integration.

2.2.7 Reliability and Maintainability

Predicting the reliability and maintainability of a new CCTV system is difficult without a demonstration period. Primary reliability and maintainability considerations include whether the new system will be able to perform the required functions over time and to what degree personnel can operate, maintain, and upgrade the system. Several techniques may be used to improve user confidence in a new installation, including:

- Conferring with security and management personnel at other facilities that have implemented similar systems or used the same vendor;
- Requesting competing vendors to run trial programs on-site or bench test equipment prior to installation; and
- Installing new equipment on a small scale in order to verify that performance meets the organization's needs.

Vendor warranty terms may require that all technicians working on equipment be certified. Some vendors may require a maintenance contract to ensure they have staff available to respond

within a specific period of time. The support requirements should be understood prior to purchase and installation of equipment. See Section 9 for more details on vendor selection considerations.

2.2.8 Annunciation, Assessment, and Response

The role of many CCTV systems in a comprehensive security program is to aid security personnel. For instance, when a security alarm occurs at a location not currently displayed on a monitor; the system can alert the operator by automatically switching the display to the location of the security alarm. The operator can then assess the security alarm visually and dispatch appropriate response forces.

2.2.9 Requirements and Design Worksheets

Table 2-1 lists basic questions to determine high level CCTV system requirements and to influence the system design.

Table 2-1. CCTV System Design Worksheet

Basic Questions for Addressing CCTV System Requirements	
1)	What areas require coverage by the CCTV system?
2)	What are the highest value assets that need to be protected? For example: • High-value material property; • Critical infrastructure; • Intellectual property; and/or • Classified material or intelligence information.
3)	Where are the sites of greatest vulnerability?
4)	Does the information technology infrastructure adequately support the number of cameras?
5)	Will the system integrate with an existing physical security system?
6)	Will the system integrate with an existing electronic access control system?
7)	Does the security budget cover regular maintenance, training, and upgrades to the system?
8)	Does the system’s installer/vendor provide adequate training to operate the system?

A sample checklist containing some of the factors to consider during a site survey is provided in Table 2-2. This checklist can be used by the design team to record the number and type of cameras, monitors, and housings as well as address connectivity requirements.

Table 2-2. Sample Site Survey Checklist

Operational Environment			
Indoor			
Outdoor			
Exposure to:			
Water			
Corrosives			
Explosives			
Fire			
Extreme Temperatures			
Location of Cameras			
Access Points: Doors/Gates			
Building Exterior			
High-Security Interior Areas			
High-Security Exterior Zones			
Hallways/Corridors			
Parking Lot			
Perimeter			
Other			
Light Levels			
Day		Night	
Lens			
Wide Angle			
Normal			
Telephoto			
Zoom			
Camera Power			
12 Volts Direct Current (DC)			
24 Volts DC			
120 Volts Alternating Current (AC)			
Cameras			
Indoor			
Fixed		Pan-Tilt-Zoom	
Outdoor			
Fixed		Pan-Tilt-Zoom	
***Total Number of Cameras**			

Housings			
Dome			
Weather-Resistant			
Tamper-Resistant			
Other (e.g., Specialized Housings)			
Mounts			
Wall		Ceiling	
Pole		Corner	
Fences		Building Exterior	
Display/Monitors			
Size ________			
Split-Screen Displays			
Multi-Screen Displays			
Video Walls			
Recorders			
Digital Video Recorders (DVRs)			
Network Video Recorders (NVRs)			
Hybrid DVRs			
Transmission			
Wired			
Coaxial		Twisted Pair	
Fiber Optics		Telephone	
Category 5			
Wireless			
Laser			
Infrared			
Radio Frequency			
Microwave			
IP-Based			
Internet Protocol (IP)-Based			
Network Storage			
Direct Attached Storage (DAS)			
Storage Area Network (SAN)			
Network Attached Storage (NAS)			
Other			

3. COMPONENTS OF CCTV SYSTEMS

CCTV uses components that are directly connected to generate, transmit, display, and store video data. A CCTV system can be as simple as a camera purchased from a retail electronics store connected to a video monitor. However, larger systems operated by professional security personnel are comprised of a number of components falling into several basic categories:

- Cameras;
- Lenses;
- Housings and mounts;
- Monitors;
- Switchers and multiplexers; and
- Video recorders.

Many features exist within each of these categories that can satisfy an agency's operational requirements in the most challenging environments. The most complex CCTV systems may incorporate hundreds of cameras and sensors integrated into one overall security network. Figure 3-1 provides a CCTV component diagram example.

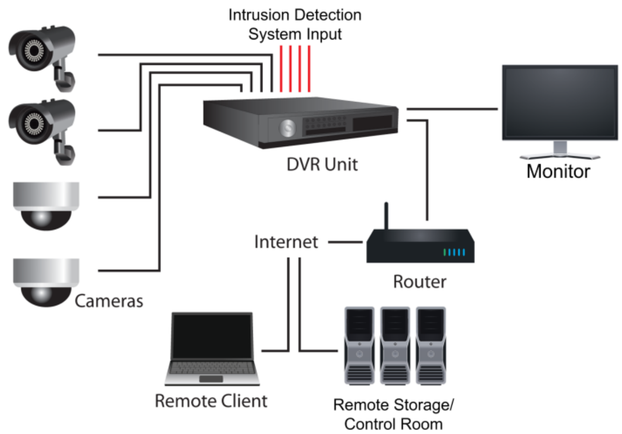


Figure 3-1. CCTV Component Diagram Example

Most new CCTV systems maximize the advantages of digital technologies by utilizing electronic databases, compact components, and wireless transmission techniques. With larger quantities of data being collected, it is essential that the system be capable of retaining data in accordance with the organization's policies and procedures.

3.1 Cameras

Cameras are an essential component of any CCTV system. Matching the right CCTV camera to a particular application is increasingly complex due to rapid technological developments and a greater range of applications. A system's performance is affected by many factors beyond those listed in the vendor data sheets. Effective camera selection requires detailed knowledge of the camera, application, supporting architecture, and host environment.

All CCTV cameras include three basic elements:

- **Image sensor–**Converts light (photons) into electronic signals;
- **Lens–**Gathers light reflected from a subject and focuses the light on the image sensor; and
- **Image processing circuitry–**Organizes, optimizes, and transmits video signals.

The type of camera best suited for a CCTV system depends on the operational environment and how it will integrate into the system. The answers to the following questions may help determine the best camera type:

- What is the desired image quality?
- What size is the desired field of view (FOV)?
- How much lighting is available?
- Will the camera be installed indoors or outdoors?
- Will the video be monitored on a full time basis?
- How will the video be transmitted?
- Will the camera be exposed to extreme conditions?

There are many types of cameras designed to perform under specific environmental conditions but cameras can be grouped into two primary categories: fixed and pan-tilt-zoom (PTZ). Fixed cameras are intended to constantly view a single scene, while PTZ cameras are motor driven and can pan left or right, tilt up or down, and zoom in or out to instantly customize the view as needed. A combination of fixed and PTZ cameras are often used to provide the required surveillance coverage.

3.1.1 Fixed Cameras

Fixed cameras are mounted in a stationary position and are focused on a single FOV, typically one particular area of interest. These cameras can be used indoors or outdoors and can be installed overtly or covertly. Fixed cameras vary in size and can be mounted in a wide range of locations (e.g., inside cabinets or control panels, or on poles, fence lines, or roofs).

Fixed cameras can be integrated with an electronic security system (ESS) and used to assess ESS alarms. For example, a fixed camera can surveil a secured gate but only record data when the gate opens, triggering an alarm. Fixed cameras are usually less expensive than PTZ cameras and require less maintenance as they have fewer moving parts.

3.1.2 PTZ Cameras

PTZ cameras come in a variety of sizes and shapes for interior and exterior uses. Typically, a PTZ camera can be turned and tilted on two axes to provide pan and tilt capabilities and the focal length of the lens can be varied to change the FOV. This enables PTZ cameras to offer more flexibility for viewing and capturing images in real time than fixed cameras. PTZ cameras can be operated manually or in an automatic scan mode, thus capturing the most relevant video possible.

In manual mode, the operator can control the direction of the camera depending on situational needs and zoom in on an object (e.g., a suspicious bag, a person's facial features, or a license plate) to capture specific details of interest.

PTZ cameras can also be configured to automatically scan back and forth over a wide area that cannot be covered by a single fixed camera. Preset positions can be programmed to switch views based upon specified time segments. For example, a PTZ camera could be programmed to change its view every 10 seconds to capture different areas of interest within the camera's overall surveillance area.

3.1.3 Connectivity Type

CCTV cameras may employ one of two types of data transmission:

Network Cameras–Network cameras connect to IP-based networks, including the Internet, and provide remote viewing and recording. Network cameras are also available in high definition (HD) which can provide greater image detail.

Analog Cameras–Despite increasing use of digital network cameras, a market for analog cameras still exists. This may be due to the cost involved in upgrading and converting to a new transmission process. Analog cameras have options for high resolution, making them applicable for various surveillance needs. These cameras also have some cyber security advantages because the coaxial cable they are connected with would require physical access to breach.

3.1.4 Day/Night Cameras

Day/night cameras offer flexibility by automatically adjusting to current lighting conditions. These cameras capture color images in daylight and switch to black-and-white to improve image quality at night. The camera relies on an analysis of the current image or a photoelectric sensor to determine when to automatically remove the infrared-cut filter and switch to monochrome settings.

3.1.5 Low-Light or Night Vision Cameras

Cameras used to capture images in dark environments are either low-light or night vision cameras.

Low-light cameras are designed to perform in some level of ambient lighting, such as indoor restaurant lighting, street lamps, or a full moon; they are not intended for use in complete darkness.

Night vision cameras used in CCTV systems typically consist of near-infrared (NIR) and IR cameras with built-in IR illuminators. They are designed to allow the operator to view night scenes. The distance from which a CCTV camera can detect objects at night depends on the capability of the camera components, such as the lens and sensor, as well as on the intensity of the IR illuminator used. The IR light emitted from these illuminators can be at wavelengths that are invisible to the human eye.

The primary determinant for whether a camera transmits an image in color or monochrome (varying tones of a single color) is the camera's image sensor. Monochrome cameras record images using light in NIR wavelengths outside the range of human perception (i.e., spectroscopic) while the image sensor of a color camera uses filters on the individual light

sensitive elements of the image sensor to limit that element to specific color wavelengths. These filters allow the sensor to detect and transmit color in addition to light intensity, which is what an unfiltered, monochrome sensor would detect.

Color cameras are used in daylight and well-lit night situations. There are many applications in which accurate reproduction of color is important. Color reference charts like that shown in Figure 3-2 provide an accurate color source for the selection/evaluation of cameras and optics. CCTV installers and technicians often use a color reference chart to assess the colors in an image. In addition, waveform generators and vector scopes are also used to measure system performance. It is important to remember that video monitor color reproduction is also critical.

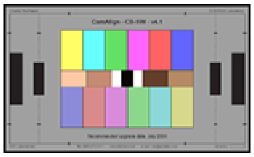


Figure 3-2.
Color Reference Chart

Monochrome cameras can capture images at night or in near-dark conditions that have more detail than the human eye can perceive. However, images captured with a monochrome camera during the day may lack some contrast and detail because the image is formed from visible and infrared light, which have different planes of focus. Monochrome image sensors are made mostly of silicon and germanium material and have two different spectral responses. This allows the image sensors to perform well in the infrared light region.

3.1.6 Thermal Imaging Cameras

Some operational environments may require a thermal imaging camera to detect through obstructions such as fog or smoke. Thermal imaging cameras detect infrared or heat radiation that is invisible to the human eye. Currently these cameras are sensitive to a temperature difference of one tenth of a degree Fahrenheit. Thermal imagers cannot detect through glass or water, but can provide an image through limited density fog or smoke.

Many thermal imaging cameras have built-in image processing to create images with improved contrast, like that shown in Figure 3-3. This provides better feature definition and sharper, clearer images. Thermal cameras are often mounted in gyro-stabilized, pan-and-tilt devices as well as on boats and helicopters for night surveillance in poorly lit areas. They are also available as small handheld units with built-in displays, which can be used in safety, security, and emergency responder applications. The image sensors in thermal cameras can degrade, so it is important to consult with the camera manufacturer to determine performance characteristics over time and to budget for the cost of periodic maintenance and replacement.



Figure 3-3. Image from Thermal Camera

3.1.7 Miniature or Covert Cameras

Special applications may exist that require the installation of small, hidden cameras as part of a CCTV system. These cameras are not usually weather resistant, so they may require an external housing if they are to be used outdoors. These cameras are typically battery operated and may use built-in transmitters to provide a compact wireless solution. Organizations can choose from many types of miniature and covert cameras depending on their requirements.

3.1.8 Optional Camera Features

CCTV cameras can include a variety of optional features to meet the specific needs of the operational environment. Some of these common features are described below.

Auto Scan–Some PTZ cameras can be programmed to perform automated functions. Auto scan is the term used to describe a constant cycle of sweeping through the surveillance area.

Preset–A preset is a programmed orientation and lens setting, which a PTZ camera moves to either periodically or when a certain type of event occurs. For example, during an intrusion alarm, a camera can be preset to display the high-value assets in the surveillance area or to focus on the access point where the alarm was triggered.

Privacy Masking–A camera with privacy masking capability can selectively block portions of the video image for the purpose of protecting privacy. For example, PTZ cameras may be used to monitor a parking lot adjacent to an apartment building with the images of the windows in the building masked. This is a feature of the system configuration (software or hardware) and can be complex and costly.

Slip Ring–A slip ring is an electrical connection that allows a PTZ camera to turn without twisting the signal/control cable. Slip rings can use light beams to optically transmit the image, or use a sliding brush contact on a base ring to create an electrical path. Slip rings tend to be sensitive to contamination and temperature changes.

Motion Detection–Cameras can be equipped with built-in motion detection features, which can be programmed to trigger an alarm if motion occurs within the FOV. The alarm can be programmed to trigger recording, alert an operator, or both. Motion detection features can also result in nuisance alarms if the environment has natural movement.

Backlight Compensation (BLC)–Some cameras have built-in BLC settings. BLC can compensate for the high contrast of images with a bright background and enhance the image detail accordingly. For example, BLC allows security personnel to see details of a person moving in front of a brightly lit window.

Digital Noise Reduction (DNR)–This feature is common for cameras intended to capture images in low-light or dark environments. DNR removes the noise (grainy appearance displayed as spots known as “raster”) from the video image. This makes the image clearer, brighter, and easier to interpret. Less digital noise can also reduce storage space requirements since there is less extraneous information in the video.

Mobile Compatibility–This application enables remote viewing of video on mobile devices such as smartphones, tablets, and laptops. Some remote viewing methods require special camera software or hardware while other methods and applications can be configured to connect directly with a camera and do not require a personal computer (PC).

3.1.9 Types of Image Sensors

CCTV cameras commonly use charge-coupled device (CCD) or complementary metal oxide semiconductor (CMOS) image sensor technology. The smallest part of an image produced on a solid-state chip is the picture element, or pixel. Regardless of the sensor type, pixels are engineered in number, size, and filtration to provide different resolutions, light sensitivity, and spectral responses.

3.1.9.1 Charge-Coupled Device Sensors

Cameras that use CCD image sensors entered the CCTV industry in the mid-1980s and now dominate the market for daylight and low-light, or NIR cameras. CCD technology has many advantages over the tubes used in the earliest video cameras. CCD image sensors are smaller, generate less heat, and their captured images are less susceptible to “blooming.” Blooming occurs when the image sensor is overwhelmed by a high-intensity light source in the FOV and eliminates details in other parts of the image. The life expectancy of a CCD camera ranges from 5 to 25 years.

CCDs consist of a three-dimensional array of pixels, each of which generates an electrical signal proportional to the quantity of light it receives. This analog electrical signal is transferred to another chip where it is converted to digital information. This digital information is processed within the camera and then transmitted to other components of the CCTV system. Some cameras convert the processed signal to analog video prior to transmission.

The surface of the type of CCD used in CCTV cameras resembles an aerial view of a very orderly city. Each of the rooftops represents a light-sensitive element, while the streets represent the electronic timing and control circuits. The proportion of the rooftops (sensor elements) to the streets (circuits) determines the sensitivity to light and the resolution of the CCD. A greater area devoted to sensor elements results in a camera with high sensitivity and finer resolution. Smaller proportions result in lower sensitivity and a more coarse resolution. In addition, some manufacturers offer CCDs with a lens capability for sensor elements to gather more light and increase sensitivity.

Although CCDs are sensitive to visible light, they are also sensitive to NIR light. A sensor’s spectral response is a function of the chemistry of some components and can be further manipulated with filtering technologies. Filters designed to reduce or eliminate IR light, known as “infrared-cut filters,” can be used in front of the sensors to improve a color camera’s image (see Section 3.6.2.8 for a more detailed discussion on filters). Monochrome cameras do not have such filters because they are intended for use near the IR spectrum. During the day, monochrome cameras form an image using both visible and NIR light; therefore, the daytime image may lack some clarity compared to nighttime images.

In order to increase the resolution, some cameras use three CCDs. In this configuration, a prism splits the white light passing through the lens into red, green, and blue. Then, three monochrome CCDs, each filtered to receive one color, calculate and combine the vector output to create a high-resolution image. The same principles can be applied to cameras utilizing three CMOS sensors.

3.1.9.2 CMOS Sensors

Applications requiring high-quality images tend to rely on CCD sensors, but CMOS sensors are commonly used in applications such as network cameras, PC peripherals, and smartphones. This is a result of CMOS sensors using less power than CCDs and being less expensive to manufacture.

Unlike CCD sensors, CMOS sensors address each pixel individually. They process the charge from each pixel on the sensor and transmit a digital bit of information. This technique reduces

the need for additional processing along the transmission pathway. CMOS sensors use less power than CCDs because a larger area of the chip is devoted to processing circuits.

3.2 Lenses

The lens on a CCTV camera is the first element in the imaging chain, which consists of the lens, camera, transmission system, image management and analysis software, and monitor. The lens focuses light or IR energy onto the imaging sensor. A lens's role is to deliver an undistorted, evenly focused, accurate image to the imaging sensor. Systems that require superior quality images start with lenses engineered to produce a high-quality image for the imaging sensor. Other components of the imaging chain cannot compensate for an inferior lens.



Figure 3-4. Representative CCTV Lens

Variables to consider when selecting a lens include the distance required to clearly focus on objects, FOV, size of the camera's image sensor, and lighting conditions. Lenses are identified by their focal length, usually stated in millimeters; largest aperture, usually stated as an f-number; and the size of the image sensor for which it was designed.

3.2.1 Types of Lenses

Lenses are available in three basic types: fixed focal length, varifocal (variable focal length), and zoom. The focal length of a lens is the distance between the optical center of the lens and the image plane. The lens focal length and the image sensor size determine the camera's FOV.

3.2.1.1 Fixed Focal Length Lenses

Fixed focal length lenses are built with one set, unchangeable, focal length. Such lenses are useful in situations where the camera remains in a fixed position and the requirements to observe an area do not change.

3.2.1.2 Varifocal Lenses

The focal length of varifocal lenses can be changed within a specific range; however, each change must be accomplished by hand at the camera. In addition, each time the focal length is changed, the iris and focus may also need adjustment. Varifocal lenses offer the flexibility of varying the scene content and are relatively inexpensive when compared to conventional zoom lenses. Once the focal length and iris are set, the camera will maintain the FOV. Varifocal lenses are identified by the focal length range, aperture range, and size of the image sensor the lens is designed for.

3.2.1.3 Zoom Lenses

Unlike the varifocal lens, the zoom lens is designed to maintain the focus setting throughout the focal length range. Zoom lenses in the CCTV industry are often built with integral motors to enable changing the focal length from a remote location. They are used on cameras that monitor different parts of a scene or can pan and tilt to monitor different locations. Zoom lenses are

identified by their focal length range, aperture range, and the size of the imaging sensor the lens is designed for.

3.2.1.4 Optical Versus Digital Zoom Ranges

The focal length ranges for varifocal and zoom lenses denote optical focal length ranges, which are a function of the components of the lens. The zoom range is referred to both as a specific range of focal lengths, such as 6 to 24 mm, and as a zoom factor, such as a 4x (four times) multiplier. For the aforementioned focal length range of 6 to 24 mm, the zoom factor is 4x (6 x 4 = 24). It should be noted that zoom factor is not an indication of image magnification; zoom factor is only indicative of the focal length range. Image magnification is a function of the image sensor size and the lens focal length. Zoom lenses are often chosen so that security personnel can use the longer focal lengths to zoom in and enlarge a specific potion of the image to see more detail or make identification.

A digital or electronic zoom refers to the capability of the camera, or the CCTV system’s processing software, to select and enlarge portions of the full image. In this case, only the selected pixels are magnified. Unlike optical zoom, digital zoom does not enhance the detail of an image, it reduces it. Digital zoom ranges are often denoted by magnification factors of 2x, 6x, etc.

3.2.2 Features of Lenses

A lens has certain components and characteristics that further determine its capabilities. These include the focal length, type of aperture and focus control, wavelength of light or energy the lens is optimized to transmit, and image sensor size the lens is designed for. Additionally, a camera’s resolution and the impact of noise on the image being captured are critical to the overall performance of a CCTV system.

3.2.2.1 Focal Length and Imager Format

The focal length and size of the image sensor determine the angle from which the lens accepts light to focus on the image sensor. Different lenses of the same focal length are designed to create a focused image on sensors of different sizes. For example, surveillance cameras are built with image sensor formats of ¼, ⅓, ½, ⅔, or 1 inch. These measures refer to the approximate diagonal measurement of the image sensor. Image sensor formats are denoted in inches, while lens focal lengths are measured in millimeters.

A lens should be selected to match the format of the image sensor so that the image formed on the sensor utilizes most of the available pixels. Lenses are generally marketed for cameras with specific sizes of image sensors. The camera’s FOV is a function of the lens’s focal length and the size of the image sensor.

Table 3-1 shows the standard focal length lenses that correspond with several camera image sensor formats.

Table 3-1. Standard Lenses for Image Sensor Size

Sensor Size	Standard Lens Size
⅔ inch	16 millimeter
½ inch	12 millimeter
⅓ inch	8 millimeter

Any lens with a focal length greater than the standard lens is a telephoto lens while a lens with a focal length less than the standard lens is a wide-angle lens. Lenses with the same focal length on a small-format camera will produce a telephoto-like image, but produce a wider image on a large-format camera. A 12-millimeter lens can be designed for the following:

- ½-inch image format camera and will produce a standard image;
- ⅓-inch image format camera and will produce a telephoto-like image; and
- ⅔-inch image format camera and will produce a wide-angle image.

A lens built for large-format cameras may be usable on some small-format cameras; however, the reverse is not true as corners and edges of the image will appear darker. For example, a lens designed for a ½-inch sensor can work on a camera with a ⅓-inch sensor, but not the reverse. It is best to use a lens designed for the size of the image sensor in the camera.

3.2.2.2 Field of View

The image sensor size and the focal length can be used to determine the FOV. As shown in Figure 3-5, the FOV is the area seen by the camera and lens. This area is commonly calculated by a tool known as a lens calculator.

Table 3-2 shows how to calculate the horizontal width and vertical height of the FOV. The FOV is calculated using the imager format information for the camera imager size, along with the distance to the object of interest and the lens focal length.

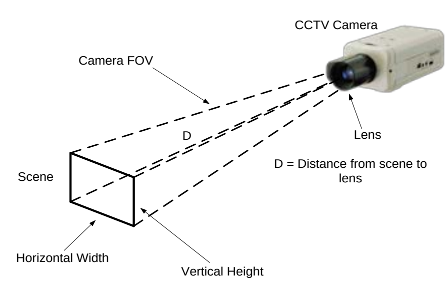


Figure 3-5. Calculating FOV

Table 3-2. Calculating the Horizontal and Vertical FOV

Imager Size	⅓ inch	½ inch	⅔ inch
Horizontal Format	4.4 millimeters	6.4 millimeters	8.8 millimeters
Vertical Format	3.3 millimeters	4.8 millimeters	6.6 millimeters
Horizontal Width Calculation: (Horizontal Format x Distance)/Focal Length			
Vertical Height Calculation: (Vertical Format x Distance)/Focal Length			
Example: Using a distance of 79 feet from a camera on a building overlooking a street, select a ⅓-inch format (imager size) camera with a 5-millimeter lens. **Horizontal width** = (4.4 mm x 79 ft)/5mm = 70 ft **Vertical height** = (3.3 mm x 79 ft)/5mm = 52 ft The camera has a coverage area of 70 feet x 52 feet at a distance of 79 feet.			

A common tool in the CCTV industry is the handheld, wheel-style lens calculator. It is an easy and convenient method for determining dimensions of a scene. Wheel-style lens calculators are widely available from CCTV vendors, generally at no cost. In addition, there are many online lens calculators, as well as software lens calculators. They range from very simple calculators that serve the same function as the handheld calculator to more sophisticated products that provide additional illustrations and simulated camera views.

3.2.2.3 Iris and Aperture

The aperture is the opening in the lens which allows light to flow through the lens. Lenses with adjustable aperture settings have a multi-leaved device, called an iris diaphragm, or iris, inside the lens. The iris diameter changes with the aperture setting. The iris diameter regulates the quantity of light flowing through the lens and subsequently onto the image sensor.

The iris ensures the optimum amount of light reaches the image sensor through the aperture, providing the best image possible. This is critical to optimal image viewing. If too much light hits the image sensor, the image will appear washed out. Too little light will result in a dark image in which only the brightest objects in the FOV are visible.

The number that indicates a lens's aperture setting is the ratio of the lens's focal length to the diameter of the aperture. This is referred to as an f-number and is calculated as:

$$\text{f–number} = \frac{\text{focal length}}{\text{effective aperture}}$$

For instance, an f-number of f/2 indicates that the lens's focal length is twice (2x) the diameter of the aperture opening.

An important feature that differentiates lenses is whether the iris is fixed or is variable with manual or automatic adjustments. Fixed aperture lenses may be useful in situations where the lighting is constant. Lenses with manually adjustable apertures are primarily useful in static viewing situations with controlled lighting. Lenses with manual adjustments cost less than

lenses with automatic adjustments, but require a technician to change the setting. There are also motorized lenses that allow the operator to remotely change the iris setting, focus, and zoom.

Lenses with automatic adjustable apertures are called auto-iris lenses. These lenses have a solenoid on them that is controlled by a video signal or a direct current signal from the camera. They are effective in outdoor environments or locations featuring extreme lighting changes.

A large aperture is an indication of the lens's ability to transmit light in dim conditions and is commonly expressed as an f-stop. The smaller the f-stop number, the wider the aperture. Common f-stop values for manual lenses include 1.4, 2, 2.8, 4, 5.6, 8, 11, 16, and 22. A setting of f/4 lets twice the light pass through the aperture as compared to a setting of f/5.6. Lenses with large apertures, such as f/1.0, f/1.2, and f/1.4, are often referred to as "fast" lenses as they allow more light to reach the sensor than lenses with a higher f-stop numbers, such as f/8.0 or f/11. Lenses with higher f-stop numbers are often described as "slow."

The aperture settings also affect the depth of field, which is the area in front of and behind an object that appears to be in focus. Higher f-stop numbers will provide greater depths of field.

3.2.2.4 Back Focus

To be useful, the image transmitted through a lens must be focused properly on the camera's image sensor. This camera adjustment is called back focusing. Cameras differ in their method to vary the distance between the imager surface and the lens's mounting surface. Most cameras have a method of moving the image sensor forward and backward. Some have a wheel that is rotated to move the image sensor; others have a screw that moves an internal mechanism. Some lenses incorporate a back focus adjustment as well. Back focus is primarily an issue with zoom lenses.

A zoom lens is properly back focused when the image of a fixed object remains sharp throughout the entire zoom range. The focus ring on the lens should not have to be touched during this zoom operation.

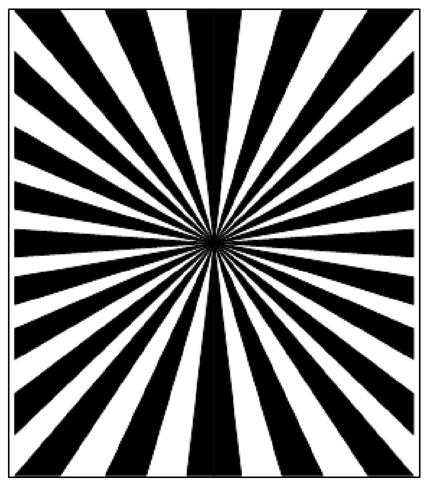


Figure 3-6. Focus Chart Example

To properly back focus a zoom or fixed lens, the lens aperture is set at the largest opening and for a zoom lens the focal length is adjusted to the longest setting. In order to achieve the largest lens aperture, use dim lighting or hold a gray neutral density filter in front of the lens to reduce the amount of light and force the aperture to fully open. An experienced technician can often focus the camera using a handheld monitor while viewing a detailed fixed object in the scene. For example, technicians may place a focus chart within the scene and focus the camera until the Moiré effect, or the moving blur in the center, is minimized.

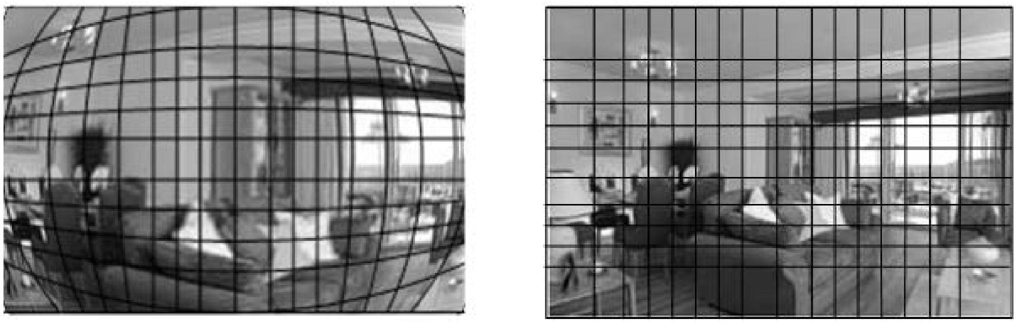
3.2.2.5 Image Quality and CCTV Lenses

A number of factors affect how light moves through the lens and forms an image on the sensor, one of these factors is distortion. There are two main types of distortion associated with image

quality: barrel and pincushion. Barrel lens distortion is related to wide-angle lenses and, in particular, a wide-angle lens that zooms. This effect causes the edges of images to appear curved, as though they are wrapped around a curved surface. An example of barrel distortion is provided in Figure 3-7.

Pincushion distortion is an effect most often associated with zoom telephotos that causes images to appear pinched in the center. This distortion increases with the distance the object is from the optical axis of the lens. Pincushion distortion is the opposite effect to barrel lens distortion.

Distortion affects the image of all objects in the FOV and the apparent relationships among objects in space. Low distortion is important to preserve correct impressions of space and objects. High-quality CCTV lenses have low distortion values, although distortion is not the only criterion of quality.



Barrel Distortion　　　　　No Distortion

Figure 3-7. Distortion Comparison

3.2.2.6 Resolution

The resolution of a camera is an indicator of its ability to resolve detail in an image. The horizontal resolution of a camera can be measured using a resolution chart, as shown in Figure 3-8. The resolution chart is composed of several, nearly parallel, lines that taper inward so lines are smaller and spaced closer together toward the bottom of the chart. As the camera scans from top to bottom, the point where the lines become indistinguishable establishes the horizontal resolution, which is indicated on the scale of the chart. The vertical resolution is limited to the number of scan lines that form the TV image and are typically not considered because they exceed the capability of the human eye.

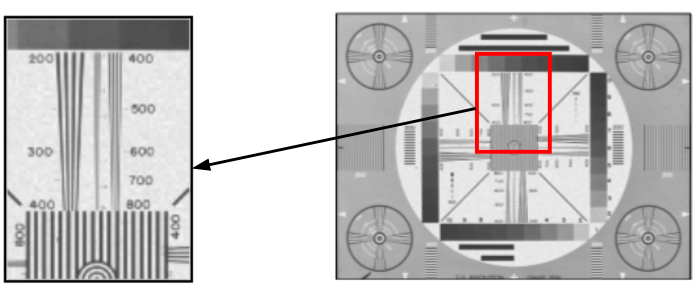


Figure 3-8. Approximately 500 Lines of Horizontal Resolution

3.2.2.7 Signal-to-Noise Ratio

All circuits produce some degree of electronic noise. The amount of noise in a circuit, referred to as the signal-to-noise ratio (SNR), is especially important whenever a signal requires amplification or processing because amplifiers and processing components can magnify the existing errors in the signal as well as introduce new errors. Noise in a video signal is viewed as graininess or snow on the screen. Video noise often becomes apparent when a camera is operating at the edge of its design parameters; for example, using a daylight color camera at dusk or in low-light conditions often produces a noisy image.

SNR values are usually given in decibels, with higher values more desirable than lower values. Noise can also originate outside the camera or system. Once electronic noise is present in a video system, it is expensive and difficult to remove effectively.

3.2.2.8 Color Corrected and Monochrome Lenses

Lenses should be paired correctly with the camera selected. Color corrected lenses are designed to focus the various colors of light onto the same image plane and create good images using color and daylight monochrome cameras. Most lenses sold today are color corrected lenses.

Monochrome lenses are inexpensive and capable of providing an adequate image on inexpensive monochrome cameras; however, they should not be used on color cameras. High-end monochrome cameras, which process reflected infrared light, should be used with lenses designed to perform well in that portion of the spectrum.

3.2.2.9 Lenses with Aspherical Elements

The glass or plastic elements used in a lens design have spherical surfaces. Computerized lens production technologies have made the manufacture of surfaces easier and cheaper, thereby providing lens designers greater leeway in correcting the light transmittance through a lens. Aspherical lenses were created to eliminate spherical aberration. Spherical aberration occurs when light from the outside of a spherical optical element in the lens converges at a different point than the light passing through the center of the same optical element. The blurring can be removed by using a modified curved lens with aspheric elements.

Designers can also create CCTV lenses with wide apertures that still produce useable images at the full aperture. Lenses with apertures of f/1.0 or faster, may be more feasible with aspherical versus traditional designs. Zoom lenses with very large focal length ranges are very difficult to design and engineer for high image quality and thus may incorporate aspherical elements. Also, aspherical lenses can be designed using fewer elements or smaller lenses while still maintaining performance similar to lenses with spherical elements.

Lenses with one or more aspherical elements may or may not produce a better image than those constructed solely of spherical elements. A well-designed, well-built lens with spherical elements may perform better than a mediocre lens with aspherical elements. The presence of aspherical elements does not necessarily indicate better performance than a lens with only spherical elements.

3.2.2.10 Filters

Filters are used to alter the amount of light or the wavelengths of light reaching the image sensor. They are often screwed onto the front of a lens, although some are integral parts of the lens design and rotate into and out of the light path. The most common types of filters used in the CCTV industry are neutral density (ND), polarizing, and IR-cut filters.

Neutral density (ND) filters are used to reduce the amount of all visible light passing through the lens when the level of the scene is too high for the camera's image sensor. ND filters are available in various densities to tailor the light reduction. ND filters are typically mounted to the front of a lens.

Polarizing filters orient light in a specific direction in front of the lens. Such filters are specifically designed to reduce or eliminate reflected light and glare from shiny surfaces, such as water or glass. Polarizing filters can be mounted on the front of a lens and then rotated to filter out the undesired light to increase the contrast of the image.

IR-cut filters are used to filter or block most of the NIR light energy that would otherwise reach the image sensor. Most image sensors have significant sensitivity to NIR light. Without the filter, the IR light from many daytime sources, including the sun, would cause the image sensor to produce an image with unnatural, unpredictable colors and poor contrast. In color day/night cameras, the IR-cut filters are mounted in a rotating filter ring inside the camera to allow the NIR light to reach the image sensor when needed.

3.3 Housing and Mounts

Part of designing and installing an effective CCTV system includes selection of the camera housings and mounts. Selecting CCTV housing and mounting hardware is directly related to the operational system requirements, which are developed during the design and procurement phases of a CCTV installation project. In any application, the housing and mounting hardware is selected on the basis of several criteria:

- Environmental conditions, which include operating temperatures and weather conditions, such as humidity and corrosion;
- Architectural considerations, which are important to the aesthetics of the hardware and can affect the architectural design or change the value of the property; and
- Installation and other special considerations that match the installed materials to the system's intended use and planned maintenance.

The following hardware and mounting options are briefly described for comparison with system requirements.

3.3.1 Camera Housing

Fixed or PTZ cameras may require special housings or enclosures to ensure cameras are protected from elements such as extreme weather conditions and vandalism. Camera housings must be well-suited to the type of equipment installed. The housing will need to complement the CCTV system design and must not interfere with the desired FOV. System requirements, such as resistance to environmental conditions, tampering, and direct assaults, can dictate the

composition and style of the camera housing. The housings listed in this section provide enclosure protection capabilities for specialized applications.

Dome Enclosures–Indoor and outdoor domes are enclosures that protect CCTV equipment, often PTZ cameras, from the elements and provide discrete video surveillance by helping to conceal the direction the camera is facing. Domes can come with built-in heaters and fans as well as vandal-resistant hardened shells. They are usually spherical in shape to minimize wind load and vibration. Various styles and configurations are available. The optical dome must be able to withstand temperature extremes and not become brittle or cloudy with exposure to solar and ultraviolet radiation. Materials that lose transparency with age in sunlight are unsuitable for outdoor camera use.

Sealed Housings–Special housings are available for cameras that must be placed in a hostile environment, or in areas where electrical components must be sealed to prevent a possible explosion. In these situations, sealed and/or pressurized camera housings are available, similar to that shown in Figure 3-9. A sealed housing uses gaskets to prevent contamination from the outside environment. Pressurized housings employ chemically inert nitrogen gas to replace the air inside the housing.



Figure 3-9. Sealed Camera Housing

Impact-Resistant Housings–Impact-resistant, or anti-vandal, housings are often used in high crime areas or as components of military sensor systems. Impact-resistant camera housing bodies, like the example shown in Figure 3-10, are typically heavy-gauge steel, and the optical surfaces are thick acrylic or polycarbonate plastic. Some versions have a wire cage over the acrylic dome to provide greater protection. Observation is not hindered because the minimum focusing distance is several feet outside the wire cage.



Figure 3-10. Impact-Resistant Housing

Tamper-Resistant Housings–Tamper-resistant housings are hardened protective housings similar to impact-resistant housings, with additional protection against the use of tools to vandalize the camera. A tamper-resistant housing is lockable and designed to withstand cutting, hammering, or prying.



Figure 3-11. Tamper-Resistant Housing

Bullet-Resistant Housings–Bullet-resistant housings are made of impact-resistant materials. The window consists of at least one thick layer of a polycarbonate material.



Figure 3-12. Bullet-Resistant Housing

3.3.2 Housing Features

Camera housings offer an array of features intended to extend the life as well as ensure the operational effectiveness of a CCTV camera. Several of these features are described below.

Sun Shields–Exposure to high temperatures may adversely affect the life of the camera. Sun shields may be used to protect camera housings from direct sunlight, reducing the heat load on the camera and lens components.

Wipers–Some camera housings employ a wiper, similar to a vehicle windshield wiper, to keep the optical window of the housing clean. However, many experts dispute the effectiveness of wipers and recommend simply waxing the optical window periodically. The use of a wiper can cause debris to erode the optical surface. Wipers also add to the maintenance requirements. Rubber wiper blades must be replaced periodically, and washer fluid reservoirs must be kept filled. Some systems use a durable film stretched over the optical surface of the housing. The film can be advanced from a cartridge to provide a clean optical path.

Heaters and Ventilators–Temperature differences between the interior and exterior of the camera housing may cause fogging, moisture problems, and icing. Therefore, certain camera housings may require additional hardware or capabilities to ensure the camera can operate under extreme conditions. Heaters and ventilators are often used to address environmental issues with cameras, although the need for additional electrical power increases the operational costs. Regular cleaning and maintenance can prevent problems with heated or ventilated camera housings.

3.3.3 Indoor Camera Mounts

The wide variety of CCTV mounting hardware and support equipment enables a security professional to tailor equipment capabilities to system performance requirements. Hardware options may become limited with an increase in specific requirements.

A camera can be mounted to a physical structure such as a wall or ceiling but may require different hardware for each application. Cameras come in many shapes and sizes and the mounting method can vary depending on the application and performance requirements. For example, a lipstick camera, often used for covert surveillance, can be placed in objects such as toys, clocks, or lights. In contrast, a nonfunctioning camera, often referred to as a “drone” or “dummy,” is simply mounted in a conspicuous location to deter unwanted activity.

Wall Mounts–Wall mounts use a bracket to support the camera similar to a shelf’s bracket. This mount often provides a method for adjusting the camera’s view or aim.

Pendant Mounts–Pendant mounts can be used to suspend the camera or equipment from a ceiling.

Corner Mounts–Corner mounts are used to attach a camera at a location where two walls meet at a right angle. There are two types of corner mounts: inner and outer. Corner mounts are often located near the ceiling to provide the best FOV.

Indoor Dome Camera Mounts–Dome mounts are sometimes mounted in highly visible areas. Domes can be partially recessed into a ceiling or mounted flush to a surface. Additionally, a dome unit can provide a platform for a PTZ camera or multiple fixed camera units. Finally, dome units should be located and installed with care to account for potential vibrations from nearby air conditioning and other electromechanical equipment.

3.3.4 Outdoor Camera Mounts

A variety of hardware is available to support and protect sensitive CCTV equipment from weather and the elements. Many of the same indoor mounting configurations are used for outdoor applications. Special mounting hardware is often required to match the styles and aesthetics of the exterior structures’ existing trim elements. The mount/bracket should

accommodate the weight of the camera and housing. If using the camera outside, plastic fixtures should be avoided because of their tendency to deteriorate and become brittle when exposed to sunlight. In addition, brackets should be selected that allow for easy repositioning either with knobs or adjustable arms. This will allow for the flexibility to position and adjust the camera to improve the FOV. Two outdoor mounting options are detailed in this section.

Pole Mounts–Pole mounts can be used to raise the elevation of cameras and provide an unobstructed FOV. Often, the stability of the camera on a pole mount is sacrificed for height. Wind-induced movement of the mount may become more noticeable as the camera's height increases. Poles should be heavy duty, galvanized metal and must be completely stable. Pole mounts typically have stainless steel spring clamps for fastening to a variety of poles. Placement of the camera needs to be high enough to prevent tampering, while positioned appropriately for the intended FOV.



Figure 3-13. Camera on Pan-Tilt Head with a Pole Mount

Corner Mounts–Corner mounts can be used for fixed or PTZ cameras, but are particularly helpful for PTZ cameras that need a large viewing angle as they pan through an area. Whenever mounts are located on or near the top of a building, the presence of adjacent air conditioning or other vibrating equipment should be noted as a potential source of blurring. Corner mounting brackets not only need to be secure and provide support for the camera, they must also comply with building codes.

3.4 Video Monitors

The function of monitors is to display video images for viewing. The selection of monitors is as important to the quality of the image as the selection of cameras, lenses, and other components in the imaging chain. The video monitor market offers a number of choices, such as liquid crystal displays (LCDs) and LED displays, various sizes, and other features. The requirements of the system will determine the type of monitor for each application. This section details some of the many features and considerations for monitor selection.

3.4.1 Pixels

The display resolution of a monitor is expressed by the number of pixels that can be displayed. To ensure the highest quality image, a monitor should be able to show at least as many pixels of information as the cameras are capable of imaging. Image quality depends on specifications and adjustments, usually described as width by height using the number of pixels. For example, an 800 x 600 pixel setting on a 17- to 19-inch monitor will provide a mid-range level of video quality. A 16:9 aspect ratio (width of 16 units and height of 9) has become a standard high definition television (HDTV) format for displaying wide screen images on televisions and computer monitors. CCTV systems using digital or IP network components exclusively may benefit from 16:9 monitors.

3.4.2 Size

Size is an important consideration when selecting a monitor and is always expressed as a diagonal measurement. Typically, it is difficult to focus a camera using a monitor with a screen

smaller than 9 inches. A 9-inch monitor may be sufficient if the operator is sitting directly in front of it; however, a 15-inch monitor is the smallest that should be used if multiple images will be shown on it.

3.4.3 Monitors

This section describes various types of monitors that are available on the market to meet an organization's CCTV needs. Summaries of the advantages and disadvantages of each monitor type can be found in Table 3-3. Table 3-4 provides an overview of video signal display types used in CCTV systems.

Televisions–HDTVs can be used to view video in certain circumstances such as viewing video for investigation purposes from a secured office. Televisions can also offer a cost-effective alternative for dual purpose monitoring of both internal CCTV feeds and network broadcasts. However, televisions do not have the same durability as monitors; therefore, it is not an advisable choice for 24-hour monitoring requirements.

PC Monitors–DVRs can be connected to a PC monitor. Inputs and outputs between these devices need to be matched using standard connectors, adapters, or converters.

Monochrome Monitors–Due to the differences in technologies, monochrome monitors have a greater potential to display detail than color monitors. Although the difference in resolution of color and monochrome monitors is narrowing, the potential loss of visual detail with a color monitor must be weighed against the cost and benefits of its display. Either type of monitor can display both monochrome and color video signals.

CCTV Monitors–Monitors designed for CCTV systems are preferred if the system will include multiple monitors and cameras, or if the monitor is always on. Monitor technologies include cathode ray tube (CRT), LCD, organic light-emitting diode (OLED), and plasma.

CRT Monitors–The CRT analog monitor is a legacy CCTV monitoring technology. CRT monitors are available in a variety of sizes. CRT monitors should include electromagnetic interference (EMI) protection. EMI can distort the path of the electron beams and reduce the quality of the image. Since CRT monitors are bulky, they are no longer used in handheld viewing devices and are seldom used in other configurations of portable equipment.



Figure 3-14. CRT Monitor

LCD Monitors–LCD monitors are available in many shapes, sizes, and resolutions. They provide a sharper, brighter picture than CRT monitors because they can process CCTV signals at a higher resolution. LCD monitors are much thinner front-to-back than CRT monitors of similar screen size so they take up less space and they generate less heat. Many are small and compact enough to be portable. They are also available in large sizes for multiple camera viewing. An important advantage of LCD monitors over CRT monitors is that LCD monitors do not suffer from magnetic interference. LCD monitors are being incorporated into many monitoring facilities in government, industrial, and corporate installations and provide more flexible viewing options than can be achieved by using banks of CRT monitors.

OLED Monitors–LED/OLED monitors use OLEDs, which emit light directly without the need for a backlight. This means that each diode can be turned on and off depending on what needs to be displayed on the monitor screen, unlike LCD displays, which require the backlight source to

be covered to produce blacks. The OLED implementation results in better contrast as well as reduced power consumption compared to LCD monitors. However, OLED display technology is more expensive, more difficult to produce, and has a shorter lifetime than LCD monitors.

Plasma Monitors–Plasma monitors are much like LCD monitors in that they are flat panels and individually control every pixel. A plasma display has a specific gas inside every pixel. The pixel elements illuminate in response to received electrical signals. Plasma monitors are available in many different sizes, although most are manufactured in a wide-screen 16:9 aspect ratio. The main advantage of plasma over LCD monitors is the greater viewing capability from an off-axis angle. Plasma displays are rapidly becoming less popular in CCTV applications due to improvements in LCD display capabilities.

Table 3-3. CCTV Monitor Technology Comparisons

Type	Pros	Cons*
CRT	• Good overall picture quality • Robust technology • Low-cost option that is compatible with most existing CCTV equipment	• High power consumption • High heat generation • High space requirements • Manufacturers have largely discontinued • Burn-in tendency (when consistent image is permanently etched onto screen)
LCD	• Compact and relatively light • Low power consumption and electromagnetic radiation • Wide range of screen sizes available • No flicker • Less burn-in. Long life expectancy (up to 50,000 hours)	• Limitations reproducing true black colors • Restricted viewing angle • Low image contrast • Time lag of pixels can lead to “smearing” effect
OLED	• Thinner, lightweight, low-power consumption, and better dynamic contrast ratio • Brighter display and wide color range	• More expensive than other monitor technologies • Shorter lifespan
Plasma	• Wider viewing angles than LCD • Higher black levels • Higher contrast ratio (the difference between the brightest and the darkest part of the image)	• Fragile • High power consumption • High heat generation • Susceptible to burn-in

*Many of the disadvantages listed are being addressed by the industry in newer products.

Table 3-4. Video Transmission Signal Display Types

Video Transmission Signal	Analog	Digital	Digital	Digital	Digital
Signal Type	NTSC	Standard Definition	Standard Definition	High Definition	High Definition
Video Quality	Standard TV	Good Picture	Better Picture	Best Possible Picture	Best Possible Picture
Aspect Ratio	4:3	4:3	4:3 or 16:9	16:9	16:9
Maximum Resolution (Digital Pixels)	480i	480i (480x640)	480p (480x704)	720p (720x1080)	1080i/1080p (1080x1920)

Notes:

NTSC–National Television Standards Committee

Interlaced Picture (i)–each frame of video is sent or displayed in two fields, all odd lines are shown first then all even lines, to create a single picture frame. Video consists of an image being created and displayed 24, 30, or 60 times a second.

Progressive Scan (p)–non-interlaced, scanning all the horizontal lines in one pass to create a single picture frame. Video consists of an image being created and displayed 24, 30, or 60 times a second.

3.4.4 Video Walls

Monitoring facilities may be designed with a wall of screens placed in close proximity to each other to display video, maps, facility diagrams, alarm points, access control, event logs, third party applications, and Internet websites. If the monitoring center will be used for other purposes such as an emergency operations center or for training, presentations, or video conferencing, it is important to make sure all requirements for use are clearly understood and identified early in the selection process. Video walls may use rear-projection monitors, thin film transistor (TFT)-LCD monitors, front projection LED tiles, or HD LCD displays. Video walls are controlled by a video wall processor, a type of video switcher, which accepts multiple inputs and processes those inputs for display on multiple monitors simultaneously.

Rear Projection Monitors–Two types of display technologies, CRT and micro-display, are used in rear-projection monitors: Micro-displays are segmented into digital light processors (DLPs), liquid crystal on silicon (LCoS), and LCD-driven displays. Rear-projection units can accept both analog and digital inputs with different image sizes. Projection technology requires lamps to create images and those lamps will burn out over time. Also, the lamps create heat and need to be cooled by fans, which require filtered air. For these reasons, it is important to factor in the maintenance and replacement costs for bulbs and filters. A comparison of monitor types is shown in Table 3-5.

Table 3-5. Rear-Projection Monitor Comparisons

Type	Pros	Cons
CRT	• Good level of performance with black colors	• Greater space requirements • Require periodic maintenance and adjustments • Narrow viewing angle • Dim picture in bright settings
DLP	• True black colors with sharp picture • Can receive HDTV signals • Thinner and lighter than CRTs • Do not require periodic adjustments	• Require periodic lamp replacement • More susceptible to low-level noise resulting in a display issue known as dancing pixels • High contrast video can also result in a rainbow effect being displayed
LCD	• Slightly better color reproduction than DLPs • Do not require periodic adjustments • Resolution is as good as or slightly better than DLPs	• Lower level of performance with black colors (improving with new products) • Require periodic lamp replacement
LCoS	• Higher resolution than other rear-projection units • Some manufacturers have discontinued production	• Color and black-and-white reproduction need improvement • Require periodic lamp replacement • Expensive technology

TFT-LCD Monitors–These flat video screens are considered superior to the classic LCD monitors. Their color quality, fast response time, and high resolution contribute to high quality video imaging. TFT-LCD walls can be used as one large screen or divided into smaller screen combinations to display different images simultaneously.

Front Projection Monitors: LED Tiles–Newer technology options include LED tiles to produce a control room display as shown in Figure 3-15. LED tiles offer minimal gaps between panels and help manage video images that span several screens with displays that offer fine details. Options are available for tiles with or without borders, depending on viewing needs. LED components have an extended life expectancy rated up to 65,000 hours at half brightness, improving the replacement frequency to 7 years or more. Generally speaking, LED technology is lighter, sharper, brighter, more energy-efficient, and less expensive to manufacture than TFT monitors. An integrated LED tile wall allows for greater flexibility by enabling images from a single source to be wrapped across multiple screens or to display separate image sources on each tile. LED tile monitors are currently an expensive option but usually require less maintenance than earlier types of monitors.



Figure 3-15. LED Tiles

HD LCD Displays–Multiple displays can be created by grouping and configuring clusters of LCD monitors on a wall like tiles. In the past, the most prevalent problem with HD LCD displays was related to burn-in. The current technology uses a method in which the image is moved so slightly that it is imperceptible to the human eye and prevents burn-in.

3.5 Switchers and Multiplexers

In CCTV systems that have more cameras than monitors and recording devices, switchers and multiplexers are used to route the video signal. Switchers are simpler in concept than multiplexers. They can be set manually or automatically to send analog or digital video to a monitor or a recorder. Some switchers can send frames or fields from several cameras to a recorder in a sequential manner, recording a frame or field from each camera in sequence.

Multiplexers, invented in the 1980s, have capabilities not available in switchers. Multiplexers receive the analog video from several cameras and digitize the signal. Multiplexers can be programmed to prioritize the video from the different cameras according to rules. Cameras covering alarmed areas in an integrated security system may be prioritized so that their images are shown on a monitor and all frames recorded. Many multiplexers have imbedded motion detection and analysis software to support the recording or displaying of an image only when the software detects movement or some other phenomenon.

Many multiplexers can be used in networks controlled by computer systems. This flexibility, when combined with digital storage media instead of tape storage systems, blurs the distinction between multiplexers and other components like digital video recorders (DVRs) and network video recorders (NVRs). DVRs and NVRs not only perform the functions of multiplexers, but also include integral hard drive storage so that video is recorded as compressed digital data. Section 3.6 provides additional information on DVRs and NVRs.

Fully digital video systems, using network cameras, do not use switchers or multiplexers. The cameras send compressed digital video data directly to DVRs, or to monitors, over an Ethernet or

other electronic data network. Digital imaging and digital storage devices are becoming standard, but switchers and multiplexers offer a low cost, easy-to-use alternative.

The primary advantage of using switchers and multiplexers in analog CCTV systems is the ability to route the video signal to multiple output devices. Section 4 addresses transmission and storage of video using IP networks. This section on switchers and multiplexers provides information about more traditional CCTV systems, which may use analog or digital components.

3.5.1 Switchers

Switchers are simpler in concept than multiplexers. They can be set manually or automatically to send analog video or a TV signal to a monitor or a recorder. Some switchers can send images from several cameras to a recorder in a sequential manner, recording an image from each camera in sequence.

Selecting the proper switcher largely depends on the number of cameras and monitors used and how the monitors will display the video. The simplest and most common devices used for small CCTV systems are the manual and sequential switcher. Most switchers provide a means to expand the CCTV system as new requirements are identified.

As CCTV systems are built with greater numbers of cameras and monitors, switchers have become more powerful and versatile. Microprocessor-based switchers have a host of features such as:

- Camera and lens control;
- On-screen text;
- Password protection for programming;
- Partitioning of video for selected users;
- Interface capabilities with additional alarm and relay panels;
- Remote viewing and control over IP networks;
- Macro programming and event timers;
- Integrated color bar generators for setting up monitors; and
- Networking for several switchers.



Figure 3-16. Microprocessor-Based Switcher

CCTV systems with large numbers of components need microprocessor-based switchers that can handle large numbers of video inputs and outputs. These are referred to as matrix switchers.

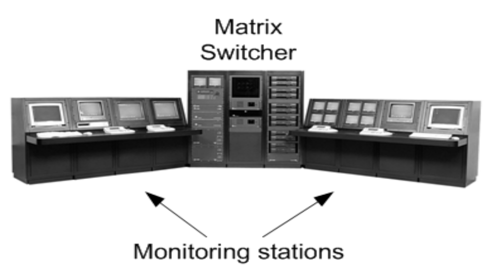


Figure 3-17. Monitoring Station with Matrix Switcher

Matrix switchers offer versatility and some can handle over 4,000 cameras and 500 monitors. These switchers have the ability to control cameras, preset positions, or pan in the event of an alarm. Software programs have been developed to handle all types of camera, monitor, and recording situations. For example, user profiles and priorities can be created for as many as 100 operators and security personnel.

Matrix switchers can often be preprogrammed at the factory to suit a client's specifications, which will save considerable installation time. The ability to upgrade software and the

availability of built-in diagnostics for the hardware are also important features in selecting equipment.

3.5.2 Multiplexers

Multiplexing began the transition from analog to digital video; these devices receive an analog video signal and then digitize it. Unlike switchers, which do not digitize the video signal, multiplexers often have imbedded software that can perform analytical tasks on the video signal, such as video motion detection. Before transmitting video data to other components, a multiplexer may convert the signal back to analog for display or recording.



Figure 3-18. Multiplexers

Multiplexers are designed to record frames, images, or fields. Security personnel can program multiplexers to prioritize the video from the different cameras according to rules. Cameras covering alarmed areas in an integrated security system may be prioritized so that their images are shown on a monitor and all images are recorded. Some multiplexers have imbedded motion detection and analysis software to record or display the image only when the software detects movement or some other phenomenon.

A number of multiplexers can be used in networks controlled by computers and servers. This flexibility, when combined with digital storage media, blurs the distinction between multiplexers and DVRs. DVRs not only perform the functions of multiplexers, but also include integral hard drive storage so that prioritized video is recorded as compressed digital data.

3.5.3 Multiplexer Networks

Multiplexers can be linked together using a multiplexer server to create systems capable of handling greater numbers of video input sources and outputs to monitors and recorders. Linking multiplexers enables the operation of a complete system with several video monitors. These networks can be programmed to perform complex sequencing.

The ability to network multiplexers brings the capability closer to that of the DVR by combining a multiplexer server with multiplexers and adding a hard drive. It is prudent to carefully consider the cost of multiplexers and associated components before discounting the purchase of a DVR.

3.6 Video Recorders

Recording capability is essential for assessment, investigation, and evidence collection. Video recording has transformed from tape-based systems to digital hard drive systems. While some systems still use tape, the popularity of digital video has driven the demand for recorders with hard drive storage. Traditional analog CCTV systems in which video is recorded to video cassette recorders (VCR) are rare in today’s environment and have rapidly been taken over by DVRs and NVRs on IP networks. Many types of recorders are being used today, but this section will focus on digital recording equipment as well as removable media and some emerging technologies.

3.6.1 Digital Video Recorders

A CCTV system may send digital or analog video to the recording system. A DVR receiving analog video takes two fields of the analog signal and builds one image, which is then digitized and compressed. If the video going to the DVR is digital, it is normally compressed to save storage space. Various data compression methods can be used that offer varying degrees of performance, quality, and storage economy.

DVRs can include a variety of features and capabilities such as:

- On-board software, such as video analytics;
- Image protection/authentication techniques;
- Ports for additional recording capabilities;
- Internal hard drive for video storage;
- Ability to easily search for and locate events;
- Ability to record one or more camera inputs while performing video analytics;
- Removable hard drive for archiving purposes; and
- Ability to transfer data to expandable storage systems called Redundant Array of Independent Disks (RAID) to free up recording space.

DVRs may be classified as simplex, duplex, or triplex. Simplex DVRs cannot record while searching and viewing recorded images. Duplex systems can record while searching. Triplex DVR systems allow the operator to view recorded and live video while recording continues.

Recording Capacity–Many components of a CCTV system need to be integrated and configured according to other device settings. For example, the method in which the system's cameras capture images will influence the amount of data the DVR needs to record and retain. Two important determinations include the frame/image size and the frames/images per second.

Frame/Image Size–This value is the average size of each image as recorded. The actual figure will be a function of the image resolution (in pixels or TV lines) and the amount and type of compression applied to the image or video sequence.

Frames/Images Per Second (fps and ips)–The number of frames/images recorded each second by a camera has a significant impact on the amount of data being generated. The preferred frame rate should be determined in the design phase. The fps or ips value can be dynamic if a camera is triggered by external alarms or motion detection. Some systems may be configured to record only when activity is detected. Other systems may provide continuous recording at a low image rate (e.g., 1 ips) until activity is detected. The system then records at a higher image rate (e.g., 12 ips) for a specified period of time.

Recording Strategies–Organizations may find it beneficial to customize the recording settings for various cameras. For example, the recording rates set for primary cameras (i.e., those that are viewed most frequently) may be set at a higher rate to allow quality viewing of movement. In contrast, the default setting for secondary cameras (i.e., those that are focused on less critical areas) could be set at a lower rate.

3.6.2 Data Compression Methods

The type of compression selected dictates the quality and amount of video data that can be stored on a DVR. Therefore, it is important to understand the differences in compression technologies. The compression aggressiveness affects how much video data can be stored on a hard drive recorder and the quality of the images during playback. If the compression is too aggressive and too many pixels are removed, faces or objects may not be recognizable.

The following example illustrates the amount of video data that accumulates over time and why compression techniques are important. A DVR will require the following storage capacity for 2 hours of uncompressed data (1 megabyte [MB] of data per image).

1 MB of data x 30 images per second
x 60 seconds
x 60 minutes
x 2 hours
=216,000 MB or 216 gigabytes (GBs)

This data storage requirement can quickly overwhelm the hard drive space of a DVR, especially when multiple cameras are being used. The number of images per second can be reduced to allow a smaller storage requirement, but the example above provides a good illustration of why compression techniques are needed.

Most organizations' DVRs serve a dual purpose: 1) high quality video recording and 2) live surveillance viewing as transmitted through the Internet or other data distribution means. This creates a dilemma in which high quality recording requires high data rates, which in turn can be problematic for efficient and fast transmission of data. If the data is compressed to accommodate faster transmission, the video quality and resolution will suffer.

Traditional compression technologies include: Joint Photographic Experts Group (JPEG), JPEG2000, Moving Picture Experts Group (MPEG)-1, MPEG-2, MPEG-4, and Motion Joint Photographic Experts Group (MJPEG). These traditional video coders compress the incoming analog video signal (input) and produce a single digital video signal (output). DVRs then use this single digital output for recording and transmission of video, thus resulting in the trade-off between data size, resolution, and quality.

Another data compression technology is a multi-rate video coder, or scalable motion adaptive coder-multi-stream (SMAC-M). SMAC-M is a proprietary video compression technique that enables multiple data output streams to meet different video recording and viewing needs.

The latest video compression standard, H.264/MPEG-4 Part 10 advanced video coding (AVC), is currently the most commonly used format. H.264 is best known as the codec standard for Blu-ray Discs™ and is widely used by streaming Internet sources such as YouTube™, iTunes Music Store®, Adobe® Flash® Player, and many more. H.264 requires half the bandwidth of other standards and allows for more effective compression, while also providing better quality, flexibility, and a variety of features such as multi-picture/inter-picture prediction and variable block size motion compensation.

Users must tailor the compression method to their needs, the surveillance environment, and objects being observed. First, the proper compression format should be selected, followed by the resolution setting. This process should allow system specialists to determine if adequate hard drive space is available.

3.6.3 Hard Drive Recorders

Standard rack-mount, hard drive recorders are generally mounted in a 19-inch rack system and may receive a number of analog video inputs: 4-, 8-, 12-, 16-, and 32-input units are typical. These units can be switched between the NTSC and phase alternating line (PAL) video standards and have power supplies that accept a 60-Hz or 50-Hz current.

The hard drive capacity is a key specification for systems without a network storage strategy, since the device hard drive will determine how many days of recording remain before the system begins recording over the oldest video. The data storage requirements will depend on the type of cameras connected to the DVR. The resolution, image rate, motion detection features, complexity of image, and FOV will also affect the unit's storage availability.

Most hard drive recorder models have the following features:

- Multiple hard drives;
- Built-in compact disk rewritable (CD-RW) or digital versatile disk (DVD) that provides permanent recording on removable media;
- Alarm inputs to trigger event recording; and
- Multiple analog monitor outputs, usually up to four.



Figure 3-19. Hard Drive Recorder for 19-inch Rack

3.6.4 Other Recording Options

Network Video Recorder–NVRs record digital video data transmitted over an IP network from multiple CCTV digital cameras. NVRs can be configured to record video in a digital format to a disk drive, portable storage device or a mass storage device. NVRs differ from DVRs as video input is delivered from an IP network. With an NVR configuration, video is encoded and processed at the camera and streamed to the NVR for storage or remote viewing. With a DVR configuration, video is encoded and processed at the DVR.

Hybrid DVR–Hybrid DVRs incorporate functions of both NVRs and DVRs by accepting and converting video images from analog cameras as well as IP video inputs. Hybrid DVRs often have IP connectivity supporting remote viewing capabilities to play back recorded video from across the network. They also allow viewing of live video.

Mobile Recorders–Mobile recorders are replacing mobile VCRs in patrol cars and on motorcycles. Mobile recorders have all the features available in a conventional DVR and are less susceptible to dirt. These recorders have become reliable recording platforms due to the advancements in immunity to vibration and motion. Many mobile recorders provide the ability to download recorded data to a memory card.

Some mobile recorders have a removable hard drive for data backup. Some also have wireless inputs and outputs for transmitting the data to a server. Mobile recorders are often coupled with other devices, such as radar guns, where the radar information is overlaid on the video itself.

3.6.5 Portable Storage Devices

DVRs can accommodate several types of portable storage media. Universal serial bus (USB) flash drives, memory sticks, and DVD+R dual layer (DL) are detailed below.

USB Flash Drives–USB flash drives allow video to be recorded or transferred. USB flash drives are available in capacities in excess of 128 GB, have a fast transfer speed, and can be programmed with password protection.

Memory Sticks–Memory sticks come in a variety of capacities up to 1 terabyte (TB). They have a fast transfer rate allowing video to be transferred to them quickly.

DVD+R DL–DVD+R DL discs have two storage layers and can hold about 17 GB of data. There are also other DVD media available, including DVD-R, DVD-RW, DVD+R, DVD+RW, and DVD-RAM. These are lower in cost but hold less data (approximately 4.9GBs).

3.6.6 Video Motion Detection

Motion detection can be built into the DVR software or directly into the camera. Video motion detection software analyzes video images frame by frame, and when a frame to frame change is detected, the CCTV system can alert the operator. In some cases motion detection can start DVR recording. The sensitivity of motion detection can be adjusted to reduce false triggers. The more sophisticated systems allow the user to define areas where motion can be ignored, such as movement of a ceiling fan or a tree branch moving in the wind. Other advanced features are available, such as object left behind and missing object detection. For more information on video analytics, see Section 6, as well as the *Video Analytics Systems Market Survey Report* available in the SAVER section of the DHS S&T website.

4. TRANSMISSION

The transmission system is an important component of the CCTV imaging chain that sends and receives video signals between the cameras, the processing system (i.e., DVRs, NVRs, and multiplexers) and the monitoring system (i.e. the display). Transmitting a strong video signal with low noise is vital to producing a high-quality image on the monitor. Many problems associated with the quality of a CCTV system signal are attributable to the transmission system.

Many types of video transmission technologies are available today. High-quality components are needed to produce a high-quality result. The distance between a camera, monitor, and storage system is one of the most important criteria for deciding which means of transmission to use. IP-based systems are quickly gaining popularity as digital formats are becoming more common within CCTV systems. Other selection factors include installation costs, existing infrastructure, and availability of power. The options described below are available when determining the best suited transmission strategy. Any copper conductor (coaxial cable, twisted pair, etc.) exposed to an outdoor environment is susceptible to noise and lightning strikes. Lightning protection is an essential added expense and could degrade the video transmission if improperly installed and maintained.

4.1 Wired Transmission

Wired CCTV systems use cables to connect cameras to other CCTV components. Wired transmission can provide good quality video images with fewer instances of interference because cables are shielded. Cameras can be located far away from recording or monitoring equipment. Three types of wired CCTV systems are commonly used today: coaxial cables, UTP cables, and fiber optic cables. Transmission over a public telephone network is not advisable for CCTV

transmission due to the cyber security issues related to an open network; however, it is still used in some CCTV environments.

4.1.1 Coaxial Cable

Coaxial cable is the most common method of transmitting video signals from the camera to the monitor or other CCTV components. Coaxial cable consists of a single wire surrounded first by a nonconductive insulating layer (dielectric), then by a braided wire shield, and finally a plastic or rubber covering. This construction is shown in Figure 4-1. Note that CCTV applications require cable of the highest quality materials and manufacture. Both the center conductor and the braided shield must be copper. Aluminum foil-wrap shield, which is used in some consumer cable applications, does not meet CCTV requirements.

Direct-run distances of up to 2,000 feet can be achieved, depending on the gauge of the cable. Cable runs across greater distances are possible, although this requires the use of amplifiers inserted in the line between the camera and monitor.

Poor quality cable can have a negative impact on reliability and image quality. As transmission through coaxial cable is electrical, it is susceptible to Radio Frequency Interference (RFI) and EMI. It is possible for unauthorized persons to acquire the video signal either through these emissions or by directly tapping into the cable.

Care should be taken to properly ground the entire CCTV system when using coaxial cable or any other form of electrical signal transmission. Improperly grounded devices and cabling can result in poor quality video, loss of video, or a grainy image.

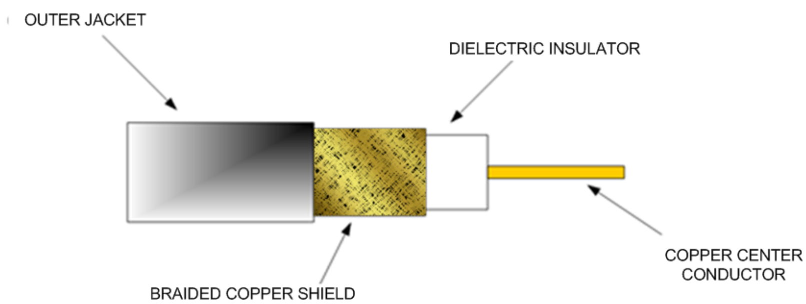


Figure 4-1. Coaxial Cable Construction

4.1.2 UTP Wire

In some cases, running coaxial from a camera to a monitoring location is not practical and existing telephone wire can be used. For example, many buildings contain abandoned telephone lines, known as UTP, which can be used for a video system. This has several advantages: overall cost savings, low susceptibility to EMI or induction, no ground loop concerns, and ease of use. Also, telephone wire is smaller and much lighter than coaxial cable. It should be noted that using abandoned telephone wire beyond a facility’s boundaries may require an approval process and service agreement with the telephone company.

UTP is comprised of two wires, twisted together. They are most often 22 or 24 American wire gauge (AWG) in size. When considering twisted pair for video transmission, unshielded twisted

pair should be used to connect only one camera to a monitor or other device. Twisted pair must be dedicated solely to a particular video camera. While the per foot cost of twisted pair wire is lower than coaxial cable, signal conversion devices (transmitter and receiver) are required at either end of the wire run. Twisted pair wire can be used in runs of up to 5,000 feet. By using repeaters at least every 4,500 feet, twisted pair can be used over greater distances.

UTP, like other electrical transmission mediums, may be susceptible to various forms of interference and unauthorized acquisition of the signal. Performance is compromised when wires are routed through a telephone switching station. This type of wire should be used for continuous point-to-point transmission and routed through “punch down blocks” or splices. The connections should have solid, zero-resistance connections.

4.1.3 Fiber Optics

Fiber optic cable is lightweight and made up of a single spun glass or plastic fiber or a group of such fibers encased in a protective covering. It has a broad bandwidth, making it ideal for carrying video signals. Fiber optic cable can be used in runs up to 6 miles without amplification. The video signal coming from the camera must first go through a fiber transmitter which converts electrical signals to light impulses. A fiber receiver at the other end is required for conversion back into electrical signals.

Fiber optic cable is immune to RFI and EMI. In addition, grounding is not an issue with fiber optics and the cable is less susceptible, if not immune, to lightning strikes. Furthermore, in systems designed with top-of-the-line components, fiber optic cable has high cost to performance ratios. A single strand of single mode fiber can carry 32 channels of analog video. In low-end systems, the expense of fiber optic cable may not be warranted. Fiber optic cable requires extremely precise installation as the most minor damage to the cable or sharp bends can cause a major degradation of the signal.

4.1.4 Telephone Network

Another option for wired transmission of video signals is the telephone network. Although standard voice grade telephone lines do not have enough capacity to handle real-time full motion video, they still have value in specialized CCTV applications. However, telephone lines are not recommended when the security of the video is a concern due to the cyber security vulnerabilities. An example can be seen in Figure 4-2.

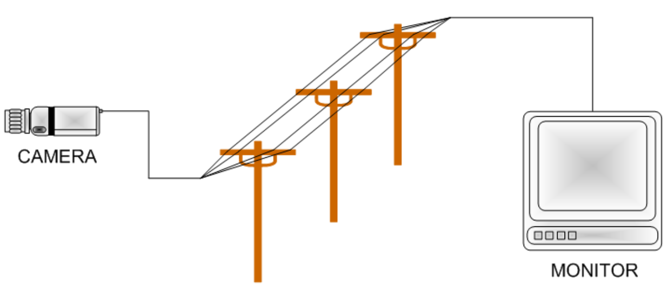


Figure 4-2. Telephone Network Example

Some CCTV systems utilize slow-scan video imaging. Instead of using the standard 30 frames or images per second, slow scan video selectively skips images. In addition, each image may be a lower resolution than standard video. Digital compression can improve this transmission method considerably.

Ongoing improvements to compression technology have made it possible to send video images more efficiently across the telephone network. Currently, one video image can be transmitted every 6 to 12 seconds over standard phone lines at 28.8 kilobits per second (Kbps).

Integrated services digital network (ISDN) phone lines have a higher bandwidth because they combine two 56 Kbps channels for a total transmission speed of 112 Kbps. This high speed data transfer rate allows one video image to be transmitted in approximately one second.

Other high speed options are available, including T-1 or Fractional T-1 lines. The T-1 family of technologies allows for multiple 56 Kbps channels to be combined, thereby achieving larger bandwidths. Very large bandwidth lines, such as T-3 or E-1 lines, may be suitable for very large CCTV systems.

4.1.5 Category 5 Cable

Networks transmit video over Category 5 cable. The cable consists of four pairs of UTP 24-gauge copper wire with three twists per inch. The high number of twists per inch reduces the "crosstalk," or EMI, between signals passing on the strands of the cable. Category 5 cables can be used to carry frequencies of up to 100 megahertz (MHz) and handle data rates up to 1,000 megabits per second (Mbps). The cables are terminated with an RJ45 connector and must meet the Electronics Industry Alliance/Technology Industry Association 568 Commercial Building Telecommunications wiring standard.

4.2 Wireless Transmission

Wireless options for transmitting video can be advantageous due to ease of installation, lack of cabling requirements, and assured mobility. There are some disadvantages of wireless systems such as the need for a dedicated frequency to transmit signals, signal interruptions, and signal interference. There are also increasing concerns over cyber security and the need for information assurance hardening. Wireless transmission options for CCTV systems are discussed below.

4.2.1 Laser

In some applications, it is impractical to install video transmission cables. If there is a direct line-of-sight between the transmitting and the receiving locations, laser or IR transmission may be used.

Applications for laser transmission versus wired transmission offer several advantages. Laser transmission systems offer the following features:

- Transmission over distances of 20 meters to 2 kilometers in clear weather;
- Data speeds from 25 MB to 1.2 GB;
- Handling of misalignments of 2.4 degrees horizontally and vertically (particularly useful for tall buildings or towers that sway in the wind);
- Indoor mounting applications that can be placed behind a glass window;

- International Electrotechnical Commission Class 1M safe (can be safely viewed by the naked eye);
- No ground loop, lightning, or induction issues;
- No license or permit requirements; and
- Difficult to tap into without being detected.

Lasers also have disadvantages. Lasers should not be placed in areas with human activity to prevent possible retinal injury. In addition, laser transmission is affected by weather, a factor that influences the feasible distance between the transmitter and the receiver. Line of sight and alignment of the signal is critical. Recent technological advances have included a narrow beam and auto tracking capabilities that tolerates fog and snow better than older laser systems. While there is always the possibility of momentary disruption, retransmission can automatically occur.

4.2.2 Infrared

An alternative to laser transmitters is an IR LED transmitter. IR LED systems may cost less than laser systems, but they often have shorter transmission distances and lower bandwidth. LED systems are also more susceptible to reflections when transmitting through glass. IR receivers should not be oriented so that they face the sun, incandescent light bulbs, or other IR light sources. When considering an IR LED transmission system, it is important to clearly understand the application and installation constraints.

4.2.3 Radio Frequency

Radio frequency (RF) is another method of wireless transmission relevant to CCTV surveillance. RF modulation of video signals is used in cable TV systems with ultra high frequency (UHF) and very high frequency (VHF) bands. RF encompasses a broad range of frequencies. Transmissions are typically focused beams, which are most efficient in open-air, line-of-sight situations. Physical obstructions such as walls or buildings are likely to degrade an RF video signal.

A typical CCTV RF system may:

- Operate on 2.4 to 5.8 GHz bands;
- Interface with 802.11 access points so that software can be upgraded via a network;
- Require Federal Communications Commission (FCC) licensing;
- Include video compression; and
- Include remote device/sensor control.

RF systems are often used when a cable installation or lease of a high-bandwidth line is impractical. Limited range is a common misperception regarding RF transmission systems. In fact, RF CCTV transmission systems can operate over long distances using directional antennas and repeaters. RF can transmit approximately 2 miles with a flat antenna array or up to 7 miles with a directional antenna. Different types of antennas can be seen in Figure 4-3.

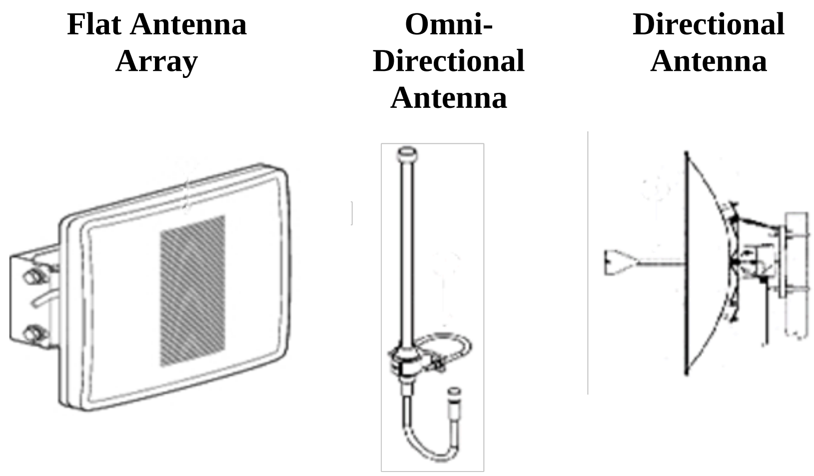


Figure 4-3. Types of Antennas for RF Transmission

RF systems have limited bandwidth, so the number of cameras that can be used simultaneously is small. If several cameras are transmitting at the same time, the signals should be out of phase with each other, and ideally any additional antennas should be facing 90 degrees away from each other.

One of the most prevalent RF video systems in the consumer market is the 5.8-GHz camera and receiver. However, the system is vulnerable to EMI and provides low-resolution images. There are other RF devices that can be used for specialized applications, but these devices generally operate on specially assigned frequencies, which require a specific license.

4.2.4 Microwave

Microwave transmission is a wireless, line-of-sight transmission medium with many similarities to laser and LED systems. Depending on its specific configuration, a microwave system can transmit video, audio, and data. Some factors to consider when exploring microwave transmission are:

- Transmissions from 100 feet to 20 miles are possible, and longer distances can be achieved with microwave repeaters;
- Microwave transmitters may require FCC licensing;
- Microwave transmission tolerates adverse weather and obstructions better than laser transmission. However, very heavy rainfall and very dense fog can affect microwave transmissions;
- Microwave systems emit at low energies, which are typically less than 1 milliwatt per square centimeter (mW/cm^2). In comparison the minimum safe radiation exposure level established by the American National Standards Institute is 10 mW/cm^2; and
- Microwave systems typically are more expensive than LED or laser systems.

Microwaves can pass through glass; therefore, mounting a system indoors to maintain an aesthetically pleasing building exterior may be feasible. The receiver and transmitter require careful alignment for optimal results. Since the signal can weaken over a long distance, it is

important to consider the distance and performance requirements carefully in the system design. Shiny surfaces, such as windows or water that are aligned parallel to the beam, may reflect energy in the outer portions of the beam toward the receiver and degrade the video signal.

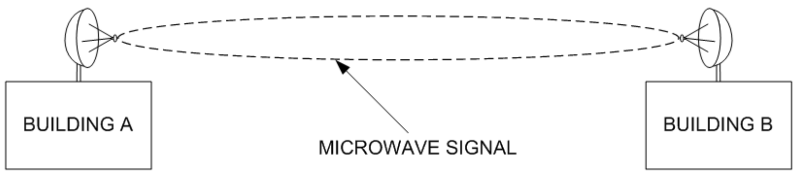


Figure 4-4. Typical Microwave Installation

4.3 IP Network Transmission

IP-based systems have emerged as an attractive alternative to other technologies, due in large part to their ability to achieve high-performance video capabilities at a low cost. The industry has found ways to implement IP-based systems that use existing cameras, cables, and other equipment. However, organizations planning and designing new systems should consider IP-based technology. This section addresses the basic parameters of an IP-based network system.

4.3.1 Internet Protocol Network System Overview

IP-based CCTV systems are designed to provide the ability to monitor, record, and stream video over a network to computers or other equipment. The system can use existing local area networks (LANs), wide area networks (WANs), and/or wireless LANs (WLANs) to save on installation costs. However, for added security, an organization could install its own private area network (PAN) cabling and support hardware. Power over Ethernet (PoE) technology is also an option within an IP-based system to increase savings and reliability. PoE enables various networked devices to receive power and data through one standard cable, which can be a significant cost savings when designing CCTV systems.

A simple IP-based CCTV system, such as the one seen in Figure 4-5, consists of a network camera (although analog cameras can be used with additional equipment), a network switch, and a PC for viewing, storing, and analyzing data and managing the CCTV system.

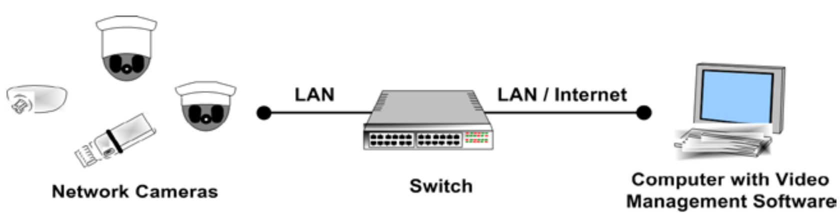


Figure 4-5. IP-Based CCTV System

Traditional analog-based CCTV systems require dedicated point-to-point cabling from each camera to the recording and/or viewing locations. In an IP-based CCTV system, video is digitized at the camera and can then be transmitted over the IP network to virtually any location

around the world. Most analog systems are traditionally unidirectional, whereas network based systems are bidirectional, easier to integrate into larger systems, and highly scalable.

Network cameras and other devices can not only send audio/video, but can also send other data like text or short message service (SMS) messages to users as well as receive audio and data (which can activate alarms, door entries, and external alarms). In addition, IP-based systems have the ability to interface and communicate with multiple parallel applications (e.g., motion detection or license plate readers).

4.3.2 Benefits of IP-Based Systems

Digital systems in general have a variety of advantages over analog systems such as ease of use, advanced search capabilities, simultaneous record and playback, improved image quality, and efficient compression and storage options. IP-based systems also provide many benefits that include:

- Remote accessibility;
- High image quality;
- Future integration with digital technologies;
- Flexibility;
- Scalability; and
- Cost-effective transmission.

4.3.3 IP-Based System Components

The flexibility of IP-based systems is attributed to the variety of configurations and types of components compatible with IP technology. Since the number of possible custom configurations is so vast, the following list is just a sample of the type of components compatible with IP-based systems.

Cameras–Both IP network cameras and analog cameras can be used in an IP-based system.

Video Encoders–When using analog cameras, a video encoder or video server needs to be connected to the analog cameras to convert the video to a digital format. The encoder then sends the data over an IP network.

Network Switches–Switches allow CCTV devices to communicate with each other and share information.

Networks–A network can be small or extensive, wired or wireless or a combination thereof. The most common approach taken by organizations is to use LANs or WANs. Network bandwidth capacity can be increased by adding switches and routers. Wireless networks are a good option when traditional wired networks are too costly or difficult to install.

Power over Ethernet–PoE is an option for using a wired network to distribute both data and power.

PC with Web Browser–PCs can access live and recorded video over the Internet as needed.

PC with Video Management Software–PCs can record and store video from cameras, as well as view live and recorded video as needed. Additionally, video management software can support video being accessed over smartphones or tablets.

Storage Devices–Video transmitted through an IP system can be stored on a server, a network device such as direct attached storage (DAS), storage area networks (SAN), network attached storage (NAS), or a PC hard disk. These storage devices are discussed further in Section 5.

Mobile Devices–IP-based systems can be easily configured to facilitate access to video via the Internet from smartphones, laptops, and other mobile devices.

4.3.4 Cyber Security

The confidentiality, integrity, and availability of data are critical for any organization. CCTV systems, especially IP-based systems, present a cyber-security risk because their video images and critical operational surveillance data is transferred and stored on a network. Protecting information should be a high priority in security planning.

Cyber security is a large and complex issue that extends far beyond the implications of a CCTV system. However, issues such as hardware and software control measures, network control measures, and network security should be considered by any agency incorporating an IP-based CCTV system.

5. VIDEO STORAGE

A CCTV system needs to be designed and configured so that it retains the necessary quantity and quality of video data. CCTV systems must also be equipped with appropriate export and archiving capabilities. An organization must clearly determine the purpose of the video that is being collected and understand how it may be used. Equally important is establishing the image resolution, image rate, and the number of days of recording that will be stored by the system. These factors will influence the use, access, recall, and storage requirements of a CCTV system.

5.1 Media Storage

Many organizations use write-once, read-many (WORM) media for long-term storage needs due to its secure and cost effective features. Current WORM technologies include optical discs such as CDs and DVDs, while older systems may use magnetic disks or tape. A disadvantage of using WORM media is that record management can be cumbersome. For example, a CD can be destroyed, damaged, or easily removed from its environment, which is not the case with data stored on servers. The storage capacity of WORM media is also a concern. It may take considerable time to copy all video data required for long-term archiving.

In contrast, a secure server with appropriate disk storage offers a central, searchable repository of video images, which can be easily accessed, recalled, and viewed by authorized personnel. Servers also enable data to be migrated automatically and suffer no loss within a RAID system. RAID storage allows images to be distributed across multiple hard disk drives to protect against a single point of failure. RAID systems conduct integrity checks and perform repairs from the parity disk if data integrity has been compromised. WORM devices have minimal to no data recovery capability if they are damaged.

5.2 Scalable Network Storage

Data storage in CCTV systems is changing rapidly and has been influenced greatly by IP-based systems requiring efficient and cost effective storage. The market offers various network storage options for IP-based systems and hybrid systems, which incorporate both analog and IP technology and communications protocols. Most organizations with a sizeable CCTV system will require network storage beyond local DVR storage capabilities. Network storage involves a physical separation of storage media from the end user. For example, storage media located within a recording device (e.g., a hard drive or DVD) has limited capacity, but network storage is independent from the recording device and offers greater scalability for the large storage demands of video images.

5.2.1 Interface Protocols

Connecting servers to storage devices is typically accomplished through use of small computer systems interface (SCSI) protocol. Within CCTV systems, SCSI is the most dominantly used storage interface. With the increase in available IP technologies and the need for interoperable and open architecture, the iSCSI protocol incorporates new capabilities to access voice, video and data from multiple types of network storage devices and make it available across an IP network. The "i" in iSCSI stands for Internet and in the simplest terms, iSCSI combines the SCSI storage capabilities with the transmission control protocol/internet protocol (TCP/IP). Network storage device options include direct attached storage, storage area network, and network attached storage. These are discussed below.

5.2.2 Direct Attached Storage

DAS is considered an older technology that was developed as a stand-alone mechanism to connect hosts to storage devices through a direct, one-to-one SCSI attachment. Adding storage and servers to a DAS system to meet demands can result in a proliferation of server and storage islands. In a DAS environment, storage sharing is limited because of its direct affiliation to the servers. DAS is still used today in CCTV systems, but external storage solutions are usually better options for CCTV video than fixed DAS storage. As LANs gained popularity, the server attached storage (SAS) was developed as an alternative to DAS in order to achieve a distributed approach via a LAN.

5.2.3 Storage Area Network

A SAN consists of communications infrastructure and management layers that ensure secure and robust data transfer. Storage appliances within the SAN contain data blocks. Operators access the data blocks when needed over the network. A SAN is a dedicated, high-performance network, typically using fiber channel technology, as seen in Figure 5-1. Fiber channel protocol and interconnect technology provide high performance transfers of block data. SANs are generally used to connect numerous storage devices such as DVRs and NVRs to one or more centralized, shared storage systems. An

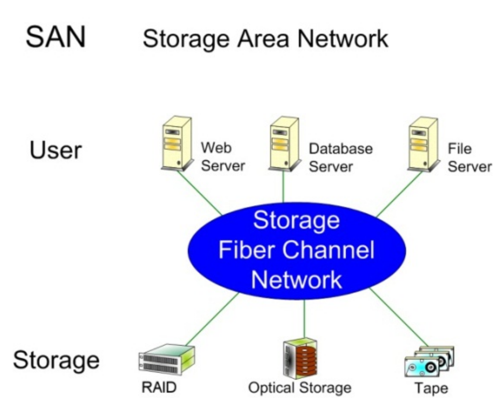


Figure 5-1. Storage Area Network

increasing number of CCTV components are being designed to connect directly to SANs via iSCSI.

5.2.4 Network Attached Storage

NAS systems record and access data in file format and consist of an engine that retrieves files from one or more storage devices. With NAS technology, servers maintain file systems on their local storage, and clients can access files at servers over a network via LAN or WAN technology, typically using Ethernet. NAS protocol is typically TCP/IP based, like the example shown in Figure 5-2. NAS is considerably less expensive than DAS and SAN; however, many considerations for the entire CCTV system will need to be evaluated to ensure NAS is compatible with other system components.

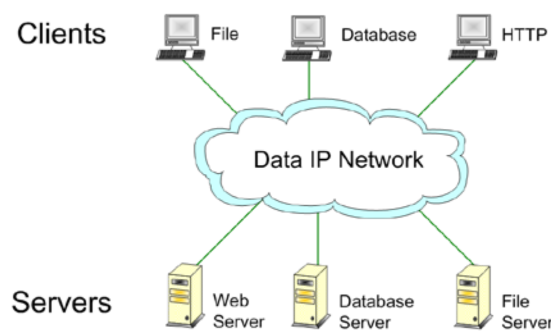


Figure 5-2. Network Attached Storage

6. VIDEO ANALYTICS

Video analytics software is often referred to as automated video surveillance, intelligent video, smart video, or video motion detection. The capabilities of video analytics are very beneficial within a CCTV system. Video analytics uses computer algorithms to monitor real-time video captured by CCTV cameras to enhance security surveillance of people, vehicles, objects, and their associated behaviors within a camera's view. Video analytics can help organizations become more efficient by automating part of the monitoring process and averting the time-consuming and tedious process of reviewing extensive quantities of stored video.

Video analytics systems can be used to identify suspicious activity in airports, train stations, seaports, and any other high traffic areas. A common application of video analytics is constant monitoring of surveillance video to provide an alert to security officers on events, such as an unauthorized intrusion in progress or a suspicious individual loitering in the parking lot. Some video analytics systems include license plate recognition (LPR), which provides law enforcement and security personnel with an automated tool to identify vehicles from the information on their license plates. Analytics applications also include traffic and tollbooth monitoring, facility and border surveillance, building and parking lot security, and identifying vehicles of interest.

Additional information on video analytics is included in the *Video Analytics Systems Market Survey Report* available in the SAVER section of the DHS S&T website.

7. SYSTEM INTEGRATION

The complexity and sheer number of components, software applications, inputs, outputs, transmission infrastructure, processing and storage devices, and customized settings of CCTV systems provide a wide range of possible configurations to meet an organization's requirements. Integrating CCTV components requires thoughtful planning when new elements are brought online to achieve new capabilities or improve performance.

Organizations benefit from system integration by removing stove-piped systems and their associated operations and maintenance costs. Integration will also improve data communications among complementary systems as well as efficiency. The training requirements alone to ensure operators understand all the features and functions of non-interoperable systems would be overwhelming. Alternatively, greater uniformity and interoperability among devices and communications architecture improves an organization's ability to maintain a CCTV system. Organizations focused on implementing integrated solutions will likely have fewer instances of compatibility issues and system failures.

7.1 Systems Approach

Organizations should strive to have all security systems and their subsystems linked together to ensure the system's components work together as a whole. Achieving systems integration is both a conceptual and a logistical challenge. Figure 7-1 illustrates the many different layers involved in an integrated security system.

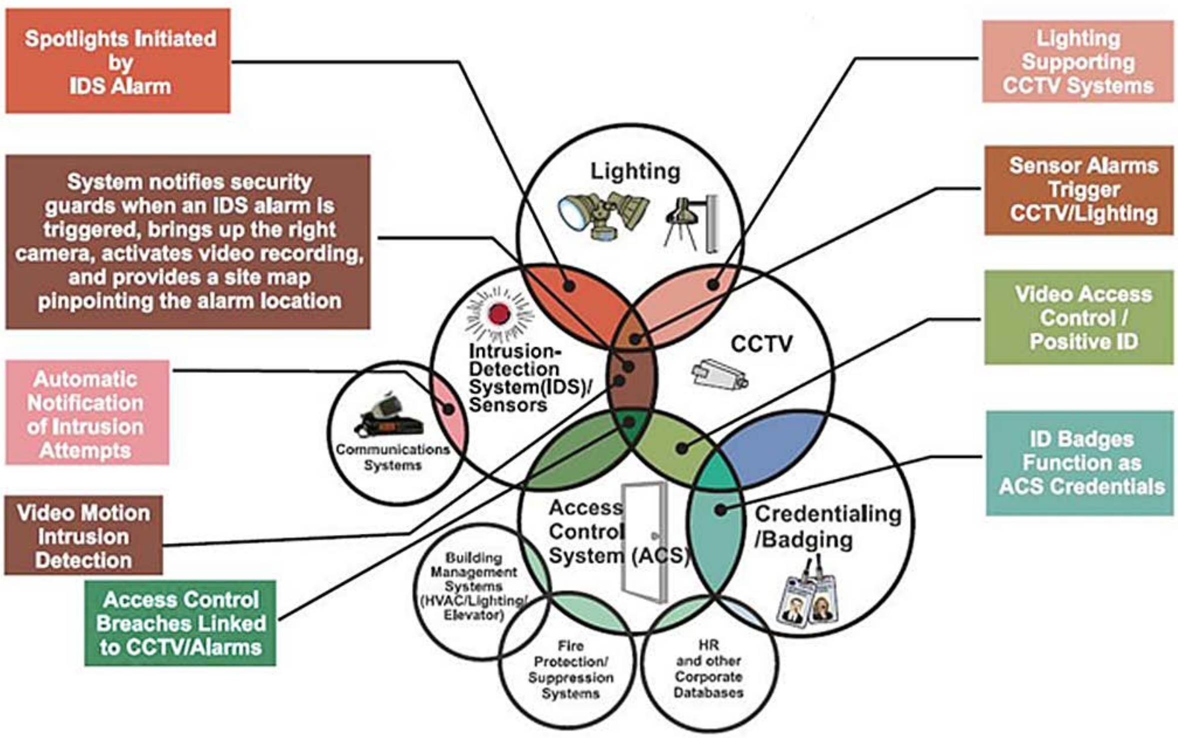


Figure 7-1. Integrated Security System

7.2 Integrating CCTV Components

Newly designed CCTV systems have an advantage over existing systems because they can be designed from start to finish with current technology components from manufacturers that are easy to integrate. When selecting CCTV devices, organizations should consider future needs and requirements, such as the potential for expansion, scalability, integration, and upgrading.

Some additional technology considerations include:

- Ability to use a consistent hardware platform throughout the enterprise;
- Off the shelf software and equipment, not proprietary;
- Compatibility for data collection and storage;
- Advanced software graphical user interfaces (GUIs) to integrate controls and displays;
- Ability to create single security user profiles used by multiple security applications; and
- Vendor support to facilitate, test, and commission system integration.

7.3 Other Considerations

An organization should consider system integration during the project planning and design phase. This applies to various types of projects that may impact the CCTV system including:

- New CCTV systems;
- Acquisition or expansion of existing structures into an existing CCTV system;
- Newly designed and built structures;
- Upgrades to associated parallel systems;
- Adding new technologies into an existing CCTV system; and
- Expansion of cameras (renaming cameras across stove-piped platforms could be a problem).

Organizations should ensure that any new projects have a commissioning process to ensure proper integration of CCTV components and enterprise system integration.

Visual tools, such as camera feeds, maps, facility blueprints, and alarm logs, available in a monitoring facility are valuable in assessing and determining the best response or course of action. Monitoring facilities can range from a small room with a single operator to a robust emergency operations center with many pods of workstations, interdisciplinary operational and planning experts, computers, printers, phones, and a video wall. Considerations for the overall monitoring facility are described below.

Room Configuration–Size, lighting, climate control, and several other factors are key elements in the overall effectiveness of the personnel monitoring a CCTV system, as well as the longevity and function of the equipment. The size of a well-designed monitoring facility is a function of the number of monitors, screen sizes, personnel workstations, and other factors. It is common for a traditional monitoring room to have a bank of 20 or more monitors. New techniques in digital video analysis are helping to reduce the need for a large numbers of monitors, but some basic rules still apply to positioning a user at a predetermined distance from the monitors. Large flat screens placed on walls offer more possibilities in facility design.

Lighting–The location, type, and intensity of lighting in a CCTV monitoring facility are very important. Light sources should be placed to minimize reflections of direct light from the monitor screens. Lighting should be indirect and either bounced off white walls or ceilings, or placed behind the monitors. Fluorescent lights should not be used because of their 60-Hz flicker

and the possibility of EMI with the video system. The brightness of room lighting should be adjustable to reduce eyestrain, and low enough that personnel can see the detail in the monitor images. Lower room lighting allows monitors to be set for lower brightness and contrast, which prolongs the life of certain monitors. Electronic handheld test pattern generators are used to achieve a good balance between room lighting intensity and the brightness and contrast settings on the monitors. Another environmental issue is flickering images, which are a problem especially noticeable in an operator's peripheral vision. Some manufacturers control flicker by increasing the scan rates.

Climate–Monitors and other components of CCTV systems generate heat. Space should be allocated around each piece of equipment for ventilation. The central monitoring facility needs an adequate air conditioning system to ventilate and cool equipment and provide for the comfort of personnel. Since monitor screens carry static electrical charges which attract dust, ventilation systems for the room should be filtered. To protect equipment from the particles and oils in tobacco smoke, smoking should be prohibited. Proper temperature control and ventilation can significantly improve the longevity of many CCTV components.

Ergonomics–Good ergonomic design in a monitoring facility is essential for the well-being and effectiveness of personnel. Building a monitoring center in an existing space designed originally for other purposes can lead to compromises in ergonomics. Comfortable and adjustable chairs, workstations with variable heights, live plants, bottled or filtered water, and consoles that are easy to navigate enhance the alertness of the operator and reduce fatigue. Monitors, keyboards, and other components should be placed at correct heights and angles to optimize personnel performance and reduce repetitive stress injuries.

Staffing–A significant consideration when planning for the staffing of a CCTV system is the number of monitors an operator can view and comprehend simultaneously for a specified period of time. More than one operator may be necessary for effective coverage in facilities with a large number of monitors.

8. EMERGING TECHNOLOGY

The CCTV industry is part of an ever-changing IT environment. New capabilities in any one of the digital components, Internet, or telecommunications industries will eventually be applicable to CCTV systems. Entities investing in new CCTV systems or upgrades are incorporating these new technologies as they become available. While it is unclear how new IT developments will be addressed by the security surveillance industry in the future, the popularity of IP-based CCTV systems in recent years illustrates how the market may respond to similar innovations. This section explores how CCTV systems may be influenced by new developments and evolving expectations from users to improve existing equipment and software. It also discusses several emerging IT trends that could factor into future CCTV products and platform integration capabilities.

8.1 Digital Technologies

Newer CCTV systems are being built entirely with digital components, from the cameras to the recording devices, and no longer require conversion back and forth between analog and digital

video signals. Computers and digital recording devices are replacing tape-based storage systems, multiplexers, and switching systems.

Since any kind of information can be digitized, CCTV systems can integrate with almost any other information handling system. They can be programmed to process, analyze, display, and store data from other media and from other surveillance sensors. CCTV can be blended into a facility's intrusion detection, access control, and alarm systems so that information from all devices is displayed to security personnel on the same displays, images, and maps. As a result, security monitoring personnel have access to multimedia presentations that merge video with radar, laser radar, sonar, intrusion detection alarms, satellite mapping, and imaging to create integrated visual situation images.

8.2 Improvements to Existing Technology

Many existing CCTV systems can be updated with current technology that incorporates new features to meet evolving consumer needs and expectations. Cameras will be made smaller and lighter and will consume less power. CCTV components are being designed to handle increased data and file sizes. Video compression algorithms are becoming more efficient, and network traffic management solutions are improving capabilities to store, retain, archive, and recall video as needed. Vendors may also focus on their product's capabilities to effectively integrate CCTV system hardware and software.

8.3 Major IT Trends

The major trends in CCTV systems are primarily related to developments in the information industry and the need for products and components to adopt new technology environments and capabilities. As new innovations related to digital formats and business-based IT solutions are realized, the CCTV industry will see a significant number of new capabilities. While some new technologies will involve hardware, the majority of emerging technologies will likely be focused on the interpretation of video through software, data storage management, and system integration.

9. VENDOR SELECTION CONSIDERATIONS

Selecting CCTV system vendors can be a challenge. Professional industry support is available from a host of companies, some of which offer a full suite of services and products. Others may offer more specialized services as designers, manufacturers, suppliers or authorized equipment dealers, installers, or integrators. The CCTV market evolves continuously with many vendors both entering and exiting the marketplace. Organizations may have internal expertise that can fill certain roles, but any new, expanded, or upgraded CCTV system will require engagement with some form of professional industry support.

9.1 Selection Criteria

Experienced vendors may provide invaluable expertise to organizations seeking upgrades of older technology CCTV systems. However, some new vendors may have more specialized expertise in a particular emerging technology. Determining the most important criteria prior to selection is a fundamental step in finding the best suited vendor. Criteria can include the

vendor's previous experience and past performance with CCTV products/services, their level of sophistication with integration of CCTV components, technical support offered, and total cost.

9.2 Vendor Resources

Selecting a well-qualified and experienced vendor with the capabilities to meet desired qualifications will help increase the quality and performance of the overall CCTV system. The following organizations' websites provide information on CCTV system vendors, their related areas of expertise, and contact information:

- ASIS International;
- Security Industry Association;
- Security Magazine; and
- SANS Institute.

APPENDIX A. GLOSSARY

The following represent terminology commonly used and/or associated with CCTV systems. Not all terms have been used in this handbook.

Angle of View–The angular measure of a lens' field of view (FOV) on the diagonal of the image, expressed in degrees or radians. Vertical and horizontal angles of view are also sometimes stated.

Aperture–The opening, located within the optical path between the front of the lens and the focal plane, that allows light to pass. The size of the aperture determines the depth of field and the time required to adequately expose an image. The size of the aperture is controlled using a multi-leaved adjustable device called a diaphragm or iris.

Aspect Ratio–A numerical expression for the ratio of the image height to the image width represented as a ratio, such as 4:3, or a number, such as 1.33.

Aspherical Lens–A lens with a surface geometry that is not derived from a portion of a spherical surface. Aspherical surfaces are much more complex to calculate and manufacture than spherical surfaces. Using aspheres allows lens designers many more options to design lenses than spherical designs alone.

Automated Video Surveillance (AVS)–See Video Analytics.

Backlight Compensation (BLC)–A video contrast control that corrects the exposure of persons or objects in front of a bright light source.

Bandwidth–A measure of the capacity of a communications channel. The higher a channel's bandwidth, the more information it can carry.

Blooming–The defocusing effect that occurs around bright areas in an image, where the intensity of the incoming light has exceeded the imager's ability to produce a usable image.

Camera Fusion–An emerging technology that allows a single video image to be created from separate video signals. Camera Fusion can integrate video signals from image sensor, intensifier, and thermal imager technologies into a single output, selecting each pixel to provide the best contrast in the final image.

Cathode Ray Tube (CRT)–The term used to denote a video terminal or television set that operates using a "picture tube."

CCTV Camera–A video camera employed in a CCTV system.

Character Generator–An electronic device that can insert text into an image. Character generators can be used to watermark an image or apply a date/time stamp to a recording.

Charge-Coupled Device (CCD)–A type of image sensor, an array of photocell semiconductors, used to create a digital image. CCDs are used in cameras, document and image scanners, and other devices.

Compressor/Decompressor (CODEC)–A CODEC is a set of algorithms for compressing and decompressing large files, such as a video file.

Color Resolution Chart–A test chart used to determine the resolution of a camera or lens in terms of color response.

Complementary Metal Oxide Semiconductor (CMOS)–A type of image sensor used in a camera to detect light and create a video image. CMOS sensors require less electrical current than CCD image sensors, and are often found in applications requiring portability or small size.

Common Intermediate Format (CIF)–A standard that defines the sizes (width and height in pixels) of full and reduced-size images. A full CIF image is 352 x 288 pixels per image. QCIF (176 x 144) contains one quarter of the information of a full CIF. QQCIF (88 x 72) is a quarter of a quarter CIF and are often referred to as thumbnails, and contain 1/16 the information of a full CIF image.

Compression–Algorithms used to compress digital image files to conserve bandwidth and video storage capacity. Moving Picture Experts Group (MPEG) and Motion Joint Photographic Experts Group (MJPEG) are examples of video compression formats.

Consumer Camcorder–A small, handheld, electronic video camera, combined with a video recorder, intended for home use.

Convex Parabolic Mirror–A bowl-shaped mirror, which creates a panoramic image that can be recorded by a camera focused on the mirror.

C-Mount (cine-mount)–One of two predominant video camera lens mounting methods. C-mount lenses have a 1-inch mount diameter with a thread pitch of 32 threads per inch and focus 17.5 millimeters behind the rear lens element. A C-mount lens can be used on a CS-mount camera (see CS-Mount) by placing a 5 millimeter spacer ring between the lens and the camera.

CS-Mount (cine-short-mount)–One of two predominant video camera lens mounting methods. CS-mount lenses have a 1-inch mount diameter with a thread pitch of 32 threads per inch and focus 12.5 mm behind the rear lens element.

Date/Time Stamp–The capability to insert the current date and time into an image during recording.

Day/Night Camera–A camera that provides color images in daylight conditions and black and white images in low-light conditions. When the ambient light falls below a certain level, an internal mechanism automatically removes the infrared (IR)-cut filter from the optical path and the camera switches to black and white mode.

Depth of Field–The front-to-back distance along a camera's axis of view where the image appears to be in focus. Depth of field is a function of the size of the imaging device, lens focal length, and lens aperture setting.

Digital Camera–A device that records a digital image or stream of images in a digital format.

Digital Imager–A fundamental component of every digital camera. The imager records the view received from the camera lens, also called a sensor.

Digital Signal Processing (DSP)–The set of algorithms or rules used to generate visual images from digital information. DSP can be implemented as software, firmware, or hardware.

Digital Video Recorder (DVR)–An electronic device that records video images and stores them to a computer storage device, such as a hard drive.

Direct Attached Storage (DAS)–A video storage technology used to connect hosts to storage devices via a direct, one-to-one small computer system interface (SCSI) attachment.

Electron–Electrons are negatively charged subatomic particles, the movement of which is the basis for electricity.

Electron Guns–CRT devices, such as televisions and computer monitors, function using electron guns. These guns fire electrons at the interior surface of the face of the CRT, which is coated with phosphor compounds. The phosphors glow when electrically charged, creating a visual display.

Electronic Noise–Static in a video system, seen as graininess or snowiness in the image on the screen.

F-Stop–The ratio of the focal length of the lens to the diameter of the aperture. The smallest number represents the widest aperture. The aperture size and the shutter speed determine the amount of light reaching an image sensor.

Fiber Channel (FC)–A high-speed network protocol and interconnect technology that provides high performance transfers of block data between networked storage devices.

Field of View (FOV)–The size of the area that can be seen while looking through an optical device. This area can be calculated using a lens calculator.

Fisheye Camera–A camera that employs an ultra-wide-angle lens that has an angle of view that may exceed 180 degrees and has considerable barrel distortion.

Focal Length–The distance between the optical center of the lens and the plane behind the lens where the image is formed. For a particular size of imaging device, the focal length determines the angle from which the lens accepts light or the angle of view.

Focus–The process of adjusting the distance between the lens and the focal plane so that objects of interest appear crisp and sharp in the final image.

High Definition Television (HDTV)–An improved television system that provides approximately twice the vertical and horizontal resolution of previous television standards.

Horizontal Resolution–The number of alternating pairs of vertical black and white lines that can be recorded by a camera and/or reproduced by a television or monitor.

Hybrid DVR–A video recording device that incorporate functions of both network video recorders (NVRs) and DVRs by accepting and converting video images from analog cameras as well as IP video inputs.

Image–A two-dimensional representation of a FOV.

Intelligent Backlight Compensation–A set of rules for changing the intensity of the pixels in an image to improve the perception of details and contrast. These rules are employed when the ambient light interferes with the details in the captured image.

Intelligent Video–See Video Analytics.

Intensifier–An electronic device that amplifies the effects of limited numbers of photons (low levels of visible light) in a near-dark FOV. Intensifiers are used to provide images under low levels of illumination from the stars, moon, or other light sources.

Interlaced Picture–Scanning two sub-pictures (horizontal lines) to make up one picture frame. Many television systems only transmit one half of an image with each pulse of analog signal. The horizontal lines of the image are divided into even and odd sets, and the video signals

alternate sending the sets of horizontal lines to the television or CCTV monitor. Systems using interlaced video signals require two pulses of video signal to make one complete image.

Infrared (IR)–The region of the electromagnetic spectrum that lies slightly past barely visible red light. The IR band starts at wavelengths greater than 750 nanometers, and extends to about 1,200 nanometers. There is no universal agreement on the boundaries of the IR band.

Infrared-Cut Filter–A filter used with an IR sensitive camera to improve performance during daylight operation. Such filters are often found on day/night cameras.

Infrared Illuminator–A light source that produces IR (invisible or barely visible) wavelengths of light. IR illuminators are used as spotlights or floodlights for cameras sensitive to reflected IR light.

Iris–The iris is the physical mechanism that can be opened or closed to change the size of the aperture.

Internet Small Computer System Interface (iSCSI)–An Internet protocol (IP)-based networking standard used for linking voice, video, and data from multiple types of network storage devices.

Joint Photographic Experts Group (JPEG)–A standard for photographic image compression. JPEG is a lossy compression method, which discards data from an image and interpolates the surrounding area.

Kilobyte (KB)–Each KB is composed of 1,024 bytes, and each byte is composed of an 8-digit binary number.

Lens–An optical device that bends or refracts rays of light to produce an image.

Light–The portion of the electromagnetic spectrum that is visible to the human eye.

Light Sensor–A device used to detect either the presence or absence of light or to measure the intensity of light present in an environment.

Lipstick Camera–A small, self-contained electronic camera often used for covert surveillance.

Local Area Network (LAN)–A network configuration used to connect computers and peripheral devices in close proximity to one another in order to share resources, such as files, applications, and printers.

Lux–The basic unit of illumination, equal to 1 lumen per square meter, or 1/10 of 1 foot-candle.

Megabyte (MB)–1 MB is composed of 1,024 KB. See Kilobyte.

Monitor Station–A workstation designed for the presentation of visual information.

Microbolometer–A type of sensor for the detection of long-wavelength IR energy, which radiates from all objects as a function of their respective temperatures. Microbolometers are one type of sensor used in thermal cameras and heat sensing devices.

Monochrome CCD Sensor–A CCD sensor that does not record color information. Monochrome CCDs are used in monochrome CCTV cameras, particularly ones used in low-light applications to detect reflected IR energy.

Motion Detection–See Video Analytics.

Moving Picture Expert Group (MPEG), **Motion Joint Photographic Experts Group (MJPEG)–**Digital formats for streams of images that record motion.

Network Attached Storage (NAS)–A network storage technology used to record and access data in file format from one or more data storage devices.

Network Video Recorder (NVR)–A software application that records video transmitted over an IP network from multiple CCTV digital cameras to a variety of storage devices.

Neutral Density Filters–An optical filter that reduces the total amount of light entering the camera evenly across all visible light wavelengths. The filter is often used to force open a lens aperture to minimize the depth of field so that the focus setting of a camera lens can be made in bright locations.

Oscilloscope–A type of test equipment used to observe electronic signals.

PAL (Phase Alternating Line)–A video signal standard used outside the U.S. The PAL standard requires 50 Hertz (Hz) electrical power distribution.

Pan-and-Tilt Devices–A movable camera platform that allows the camera to be aimed or pointed at objects of interest.

Panoramic View–An unbroken view of a wide arc (often 180 degrees or more) of a horizon.

Peltier Cooler–A type of electrically powered heat sink used to cool electronic devices that have performance degradation when operating at higher temperatures.

Personally Identifiable Information (PII)–Unique personal information that can be used in conjunction with other resources to identify, locate, or contact a specific individual.

Phosphor Elements–The chemical compounds which line the inner face of a CRT video display. The phosphor elements glow when struck by the streams of electrons, producing the picture seen on the CRT.

Photon–In quantum physics theory, a photon is a single discrete unit of light or a packet of light.

Pin-Hole Lens–A small, fixed focal length lens often used in covert camera applications.

Pixel–A picture element, the smallest component of a visual display. The resolution of a video monitor is proportional to the number of pixels used to generate the display.

Polarizer–A special neutral-gray colored optical filter that can be rotated to selectively pass light oriented along a very narrow axis relative to the filter. The light originating from outside the axis is blocked. A polarizer is often used to reduce or eliminate reflections from window glass and water surfaces.

Pyroelectric Sensor–A type of sensor device for the detection of thermal infrared radiation.

Resolution–The term resolution is used to express the level of detail that can be captured by a sensor, camera imager, or camera, or displayed by a video monitor. Resolution applies to the horizontal, vertical, and color characteristics of the details in an image.

Resolution Chart–A printed graphic used as a target image, a resolution chart provides a demonstrated system performance value, which can be compared with stated parameters to determine if a system is functioning normally.

SECAM (Sequential Color and Memory)–A video transmission format used in France and other nations.

Sensitivity–Relates to the minimum quantity of light required for the camera to produce an image, as well as to the resolution of the camera imager. Images taken at high resolutions require more light to produce.

Server Attached Storage (SAS)–A data sharing storage technology that was developed as an alternative to DAS in order to achieve a distributed approach through the use of a LAN.

Signal to Noise Ratio (SNR)–Expresses a performance characteristic of a camera's ability to produce a clean and clear image. SNR values are usually given in decibels (dB), with higher values more desirable than lower.

Small Computer System Interface (SCSI) Protocol–A set of command, protocol, and interface standards used for connecting and transferring data between computers and peripheral devices.

Smart Video–See Video Analytics.

Software Algorithms–A problem-solving procedure composed of a series of steps or instructions. Any useful computer program contains a set of algorithms.

Storage Area Network (SAN)–A data sharing storage technology that consists of communications infrastructure and management layers.

Thermal Camera–A camera that creates an image from the thermal IR radiation emitted by objects. The IR energy radiated from objects depends on the objects' temperatures and is displayed as different colors or shades of gray.

Third Generation Intensifier–The newer generation of image intensified night vision technology often found in tactical equipment such as night vision goggles.

Transmission Control Protocol/Internet Protocol (TCP/IP)–An Internet communication protocol that defines rules for data format, addressing, routing, and transfer so that computers can communicate with one another.

Vector Output–A method for combining multiple inputs into a single output.

Vectorscope–An oscilloscope used to set up and measure the chrominance portion of a video signal.

Video Analytics–A technology that uses software to analyze the video image stream. Video analytics software may provide object detection, recognition, identification, tracking, and analysis in a variety of surveillance applications.

Video Motion Detection (VMD)–When the current image changes beyond a threshold value, the system triggers one or more pre-programmed actions and initiates an alarm.

Video Monitor–An electronic device for displaying video output that may be digital or analog.

Watermarking–The process of adding a semi-transparent layer of verbal or visual information onto an image. Watermarking is often used as part of an authentication process.

White Light–White light is made up of all colors of the visible portion of the electromagnetic spectrum, from about 500 nanometers to about 700 nanometers.

Zoom Lens–Zoom lenses are variable focal length lenses that are designed to maintain a focus setting throughout the zoom range. Many zoom lenses have an integral motor that allows remote operation of the focal length setting.